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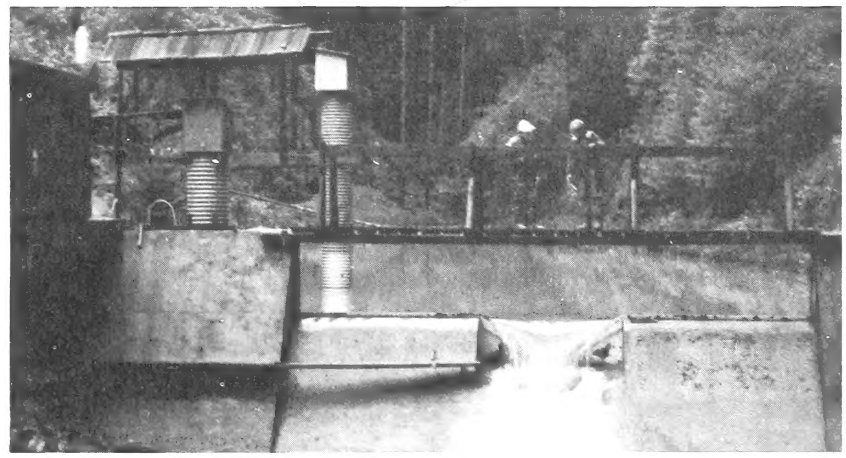
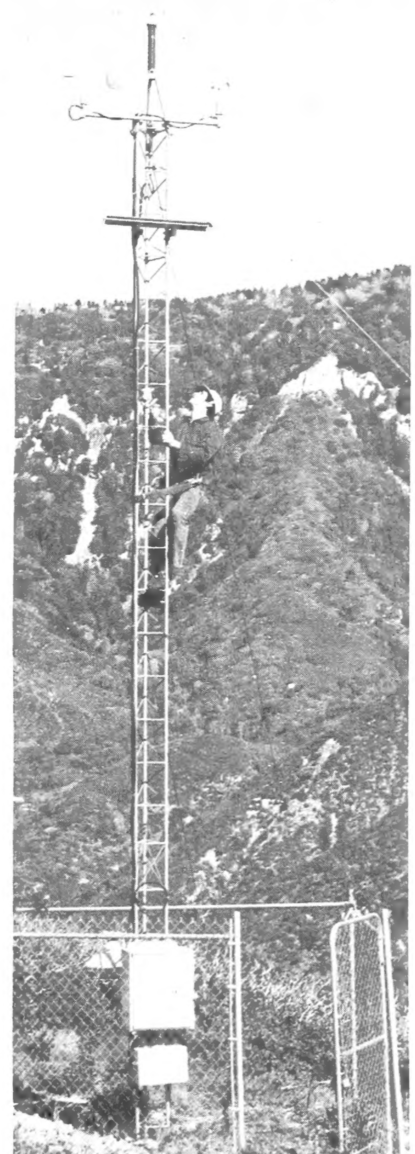
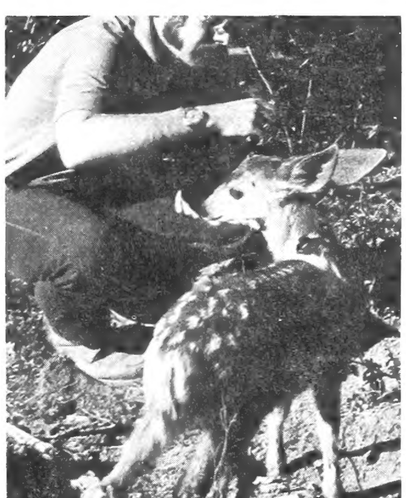
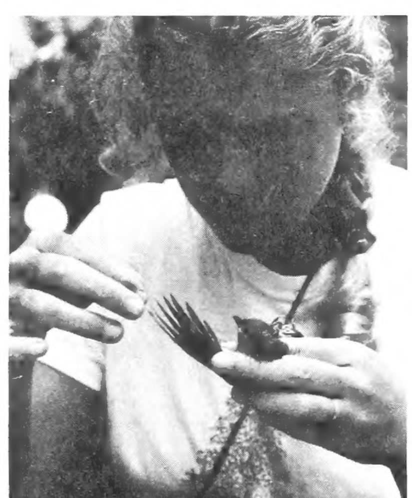
Criteria for Deciding About Forestry Research Programs

Criteria for Deciding About Forestry Research Programs

Technical Coordinator

Robert Z. Callaham
Pacific Southwest Forest and
Range Experiment Station

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Abbreviations Used in This Report

Agencies, U.S. Department of Agriculture
- ESCS = Economics, Statistics, and Cooperatives Service
- FS = Forest Service
- SEA = Science and Education Administration

Other Agencies
- F&WS = Fish and Wildlife Service, U.S. Department of Interior
- NIH = National Institutes of Health, U.S. Department of Health and Human Services
- NSF = National Science Foundation

Branches, Forest Service, U.S. Department of Agriculture
- NFS = National Forest System
- S&PF = State and Private Forestry

Research Stations, Forest Service, U.S. Department of Agriculture
- FPL = Forest Products Laboratory
- INT = Intermountain Forest and Range Experiment Station
- NC = North Central Forest Experiment Station
- NE = Northeastern Forest Experiment Station
- PNW = Pacific Northwest Forest and Range Experiment Station
- PSW = Pacific Southwest Forest and Range Experiment Station
- RM = Rocky Mountain Forest and Range Experiment Station
- SE = Southeastern Forest Experiment Station
- SO = Southern Forest Experiment Station

Others
- APD = Alternative program directions
- FY = Fiscal year
- GNP = Gross national product
- MAB = Man and the Biosphere Program, U.S. Department of State
- IUFRO = International Union of Forestry Research Organizations
- R&D = Research and development
- RPA = Forest and Rangeland Renewable Resources Planning Act
- SAES = State Agricultural Experiment Stations
- SY = Scientist-year
- USDA = U.S. Department of Agriculture

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Executive Summary

In early 1979, the Forest Service, U.S. Department of Agriculture, was required to decide several significant issues affecting its future research program. These decisions were in response to requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA).[1] The decisions required information that was not either available or assembled. Most important, the criteria upon which the decisions should be based had to be defined.

Managers of Forest Service Research responding to this need visited 14 other Federal agencies conducting research. They searched, but to no avail, for precedents, examples, or guidelines for transfer to the situation facing the Forest Service. The Forest Service is in a unique situation: it is a subpart of an operating agency but has a broad array of outside clients. The size and growth of Forest Service Research should, therefore, be related to changes both in other research organizations—particularly those in USDA—and in other parts of the agency—particularly the National Forest System.

Policy on Federal and other public, versus private, support for research and development was examined. Most basic, much applied, and some developmental research are public responsibilities. Public support for research particularly is justified when results cannot be captured in the market place and when they contribute to broad social benefit, long-term economic growth and productivity, and well-being of natural resources, the environment, and future generations.

Public investment in research may be justified when public interest is not adequately served by privately financed research, as is the case in forestry. All indications are that more public funds should be committed to research on renewable natural resources and that returns on investments will be high enough to justify substantial increases.

The first set of four criteria for evaluating research program alternatives in the Forest Service emerged from this effort:

- Response to needs, primarily national, regional or special needs for which technology is inadequate, for emergency problems, and for the public's well-being;
- Contribution to productivity and other returns, including both quantifiable and nonquantifiable benefits;
- Response to national policies, particularly those enunciated by the executive and legislative branches of the Federal Government;
- Relation to historical trends, reflecting recognition that the course of research should not change drastically and should relate to changes in demand for technology.

Needs for research are generated by legislative mandate, expressed by users of technology, and identified by scientists. Broad research needs of users were expressed at regional and national planning conferences during 1977 and 1978. USDA's national and regional planning process also identified research needs. Twenty-one forestry research plans developed during recent years point to special needs. Basic research and international forestry research have especially important needs. All of these needs were assessed and considered in the light of alternative program directions proposed for Research under RPA. Only the alternative programs financed at the highest levels proposed were fully responsive to national needs.

Understanding the breadth and diversity of the clientele for forestry research, one can appreciate the need for such research. We estimated that more than 48,000 professionals in 42 broad disciplines and employed by more than 40 agencies constitute the Federal clients for forestry research. Data from professional societies, indicating that about 25 percent of their members are Federal employees, led us to estimate that about 200,000 resource professionals in the Nation utilize Forest Service Research. Private landowners, resource-dependent industries, educators and students, legislators, citizen groups, homeowners, and the general public add unestimable numbers of clients for Forest Service Research. The public well-being is served by forestry research through the knowledge and methodology it provides for these many sectors of our society.

Contributions to productivity and other returns to society from research have been repeatedly demonstrated. Growth in productivity in the United States has slowed in recent years, and some have suggested that declining investment in R&D is a significant cause. The decline in productivity in the United States contrasts with growth in productivity in other developed countries. Improved technology, availability of capital, and improvements in labor are major contributors to growth in productivity. Improvements in technology resulting from R&D contribute 30 to 70 percent of the growth in productivity. However, such measures of the contribution of R&D to productivity are still in the fledgling stage.

Internal rates of return from several areas of agricultural research, as compiled from many studies, are in the range of 30 to 40 percent. Such rates of return and current expenditures for research argue strongly that the Nation is underinvesting in agricultural and forestry research. Although internal rates of return from forestry research have not been estimated, knowledgeable economists expect that such returns will parallel those from agricultural research.

For the first time we have made a hindsight review of outputs and benefits from Forest Service Research. The objectives of the review were: (1) to determine the magnitude of benefits and costs associated with a wide range of recent innovations; and (2) to describe important factors contributing to successful innovations. Eighty-one innovations were selected to meet the needs of RPA and to illustrate the array of benefits. Responsible scientists described what happened, when and where it occurred, how it happened, and who was involved. Each innovation was evaluated as to the kind and amount of benefits

[1] All symbols used in this report are explained on p. ii.

accrued, costs for research in terms of scientist-years and time required, and factors influencing the innovative process. More than 16 general categories of benefits were found to result from Forest Service Research. At least half of the innovations resulted in benefits, such as creation of income or employment, increased utilization of natural resources, and improved quality of environments. In 40 to 50 percent of the cases, new or improved products resulted, decisionmaking was improved, management costs were reduced, or lower prices and costs for commodities resulted. Other benefits, occurring less often but significantly, were reduced costs, improved efficiency, and enhanced well-being of the public. The first-year benefits alone, \$2.6 billion, exceeded the cost of all prior Forest Service Research. Considering that many other quantifiable and nonquantifiable benefits have resulted, a logical conclusion is that such research yields a high rate of return.

The innovative period was found to be long but variable. The average time from the first conception of an innovation to the first description of the entire process was 5.4 years. The direct program period, leading to first realization and general availability of an innovation, required another 9.9 years. The average innovative period was 15.3 years. One quarter of the innovations only required 3 to 8 years, but the fourth quarter of all innovations required 21 to 48 years. Costs, in terms of scientist-years (SY's), reflected a similar distribution, averaging 5.4 SY's during the conception period and 16.5 SY's during the direct program period. Based on values in 1977, costs of these innovations averaged \$2.52 million, but ranged from \$200,000 to \$14.8 million.

The innovative process was found to be determined by 22 factors. Most frequently innovation was influenced by utilization of existing technology, techniques, or equipment and by process or pilot testing. Other significant factors were cooperation and personal contacts with users; theory development; computer capabilities; publication of intermediate results; changes in legislation, policy, or standards; development of special equipment; or demonstrations. The probability of successful innovation depended more on factors taking place during the conception period, before direct research was begun, than on technology transfer efforts during the post-innovation period.

National policy on science and technology should influence decisions about Forest Service Research programs. Unfortunately, a succinct statement of national policy on science and research does not exist. Therefore, we gleaned messages, speeches, reports, and hearings to suggest policies to which Forest Service Research should conform. They stressed these considerations: maintaining continuity and consistency in support and policies; recognizing the long time required to train scientists and to conduct research; and leadership by the Federal Government in investing in the Nation's future. The Federal Government now is providing for real growth of basic research. High productivity gains in the future depend upon new technology and will contribute to reducing inflation. An urgent need is for facts and uncontrovertible data as a basis for decisions. The public sector is underinvesting in agricultural and forestry R&D. Few opportunities for public investment can compare with the rates of return on agricultural and forestry research. Competitive grants and base funding both are important for major forestry research performers. Every major department of government should manage enough science to assure the quality of the technology it uses.

Constrained Federal employment is a part of current policy that is likely to affect Forest Service Research in the future. Our investigation disclosed that: (1) the proportion of appropriated funds obligated directly for extramural research had climbed to about 10 percent in FY 1979 as ceilings on employment tightened; (2) a nearly equal amount was spent intramurally for management, support, and scientific input; (3) a sizable supply of scientists would be available if extramural research were to expand considerably; (4) budgetary increases up to a level of about \$130 million would saturate our capacity to manage cooperative aid research; (5) beyond that level, contracts, R&D programs and "captive laboratories" would be funded; and (6) each \$10 million increase in appropriations, beyond the level of about \$130 million, would require redirecting 55 to 60 positions into management of extramural research. Ceilings on Federal employment do not seem to affect decisions about levels of funding for Forest Service Research.

Our look at historical trends showed the paths followed by research in recent years and provides another basis for decisions about research programs in the future. National expenditures for R&D have followed a downward trend until just recently, but now the indication is that Federal funding for R&D is rising. Other developed countries are still increasing their relative investments in R&D. Forestry-related industries rank among the lowest major industries in expenditures for R&D. National expenditures for forestry R&D are estimated at about \$331 million in FY 1978. About 42 percent of the funds are Federal, including 36 percent for the Forest Service. The relationship between expenditures for forestry R&D and for management of forest land and resources is unbalanced; for example, timber management research gets relatively more than range management research.

Forest Service expenditures for R&D have increased 31 percent since 1969, in constant 1972 dollars. Most increases were targeted for specific problems and locations. In constant dollars, research on timber management, range management, and wildland recreation actually has less money in 1978 than in 1969. Under the 1975 RPA program, Research within the Forest Service failed to keep pace with expansion of forest land management on the National Forest and the associated needs for technology. This failure is reflected in the growing incapability of Research to respond to demands of land and resource

managers. During this same period Forest Service Research grew slowly and fell behind agricultural and forestry-related research in other Federal agencies. The growth of Research in the Forest Service slowed dramatically during the past 5 years.

Forest Service Research today was shaped by a long chronology of events influenced by many factors. We looked into its balance geographically, functionally, and structurally. Distribution of funding among Experiment Stations and broad geographic regions has been relatively stable, but with some notable ups and downs among Stations. Criteria for distributing funds geographically were identified, but their use in decisionmaking is befuddled by politics, tradition, and many other factors. Funds for functional activities are imbalanced because funding for research has not kept pace with increases in funding for management of Federal lands and resources. At the national level research functions most deserving of increases are: economics and marketing, recreation and environmental values, watershed management, and timber management. The major recent force shaping regional and functional differences in Forest Service Research programs has been political considerations. The RPA process should be the place for objective, apolitical decisions to achieve desirable balance in the program for Research.

During the spring of 1979, the Forest Service sent drafts of RPA's "Assessment" and "Program" documents to the public for review and comment. Twenty percent of 1,625 respondents commented on Forest Service Research. Most commented on specific areas of research and supported increased research effort and program funding. Areas suggested for increased research emphasis covered the full spectrum of problems and priorities expressed elsewhere. Public preference for RPA alternative program directions was variable, but most seemed to favor the highest to moderate levels or modifications thereof.

This quick review of the position of Research in the RPA process merely pulled together available information and repackaged it as a framework for current decisions about Research. Another outcome of this review was identification of gaps in basic information pertaining to Research. An assessment of forestry technology is our greatest need. Improvements in our evaluation of productivity and accomplishments of forestry research programs are urgently needed. Other data needed relate to trends in research and related areas; outputs, benefits, and costs; users and clients; and criteria for programmatic decisions. Answers to a long list of questions should be generated by ongoing investigations, so Research can not only fulfill its obligations within the RPA process but also increase its capabilities to produce innovations required in the future.

Introduction

In early 1979, the Forest Service, U.S. Department of Agriculture, had to decide several significant issues affecting its future research program. Decisions would respond to the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA), which calls for a periodic assessment of the Nation's renewable resources and a recommended program. But decisions to be made required information that was not either available or assembled. Most important, criteria for decisions had not yet been defined. A special task force comprised of managers of Forest Service Research was organized to collect required information, propose criteria for decisions, and identify needs for further effort.

This report summarizes the findings of the task force. In a sense, it represents a taking of stock in 1979 by managers of Forest Service Research—the largest single forestry research organization in the world.

The RPA requires the Forest Service to assess every 10 years, starting in 1979, the status of America's renewable resources of the forest, range, and other associated lands. This assessment looks at the demand for and supply of the renewable resources. It inventories the present and potential renewable resources and determines their status. It evaluates opportunities for improving the yield of tangible and intangible goods and services. The assessment is to include descriptions of the Forest Service Research programs and responsibilities and their relationship to public and private activities. The RPA also requires the Forest Service to recommend a renewable resource program, including program alternatives that address needed research. Furthermore, the program is to include a detailed study of personnel requirements needed to satisfy the existing and ongoing programs.

These requirements for an assessment and a recommended program caused managers of Forest Service Research to take a hard look at the needs for technology to manage the Nation's renewable resources and to propose alternative programs of research to meet these needs. In 1977 and 1978, the Forest Service had conducted a series of regional and national working conferences in cooperation with the Association of State College and University Forestry Research Organizations and the National Association of State Universities and Land Grant Colleges. Delegates to these conferences identified and assessed research problems for forest and associated rangelands. Representatives of governmental, industrial, consumer, environmental, and conservation organizations listed problems needing research and assigned priorities to those needs. The conferences stopped short of recommending the level of effort on each program and need. The RPA proposed program for 1975 through 1980 had projected a level of research effort to 1985. Therefore, forestry research managers simply tailored the listed problems and priorities to fit the number of scientist-years (SY's) projected for 1980 and 1985 by the first RPA program.

As the Forest Service completed its second assessment and started planning its alternative program levels for 1981-1985 and subsequent time periods, research managers realized that the criteria being proposed for decisions about natural resource management were not suitable for decisions about research programs. What was needed were criteria and further information for deciding about the adequacy of our technology and research effort for managing forest and rangelands. Answers were required for such questions as: How much funds are required for research? How fast should funds be provided? Why are funds needed now? And why should funds be provided by the Federal Government in current times of economic stringency?

Managers of Forest Service Research, with insight from leaders of research programs at forestry schools, undertook to answer these and other questions (table 1). Individuals and small teams, working with limited time, compiled the available data and information. From their effort emerged the criteria for decisions on Forest Service Research programs. This process yielded some astounding data, enabled decision-makers in the Forest Service to learn more about research and the nature of the scientific process, and identified topics requiring further study or better data to improve future decisions. All who participated learned much. Forestry research in the future should profit greatly from this unprecedented look at "Research in the RPA Process."

Table 1—*Tasks undertaken in the study of Forest Service Research and participants*

Task	Forest Service[1]	ASCUFRO[2]
1. Develop criteria for selecting the program for research.	Burns	Richard A. Skok, Univ. Minnesota
a. Analyze needs of major users (public and private) for research and identify unique needs, if any, of specific users.	Smythe Loftus Estep	Irving I. Holland, Univ. Illinois
b. Analyze the responsiveness of the five alternative or other research programs to meet needs stated or implied by National/Regional research plans, the Renewable Resources Planning Act Assessment, Section 6 of National Forest Management Act, Regional Foresters, etc.	Cooper Foulger	Hugo H. John, Univ. Vermont
c. Analyze long-term, national trends in research in relation to economic growth and productivity and to other societal values and benefits.	Smith Bohannan Lennartz	Jay M. Hughes, Univ. Colorado
d. Display findings, conclusions and recommendations on status of and needs for science and technology.	Duvall	Emmett F. Thompson, Univ. Alabama
e. Develop the logics for and against support for R&D from Federal and State resources.	Lloyd	Donald P. Duncan, Univ. Missouri
f. Determine the criteria other Federal and State agencies use to evaluate and select programs for research.	Lloyd Koning McFadden	Donald P. Duncan, Univ. Missouri
g. Estimate the number, diversity and employment of users or outputs from forestry research and their dependence upon research done by the Forest Service.	Hubbard Hough P&A AD's[3]	Dennis E. Teeguarden, Univ. California
h. Estimate effects on research programs of ceilings on Federal employment.	Guilkey Scheer McSwain	A. C. Mace, Jr., Univ. Florida
2. Evaluate past and proposed future Forest Service research programs.	Shafer	
a. Estimate payoffs of selected innovations that resulted from Forest Service Research.	Moeller Cordell	Richard A. Skok, Univ. Minnesota
b. Estimate potential payoffs from proposed future research programs.	Moeller Cordell	Irving I. Holland, Univ. Illinois
c. Review planning for and payoffs from research done by others, but on problems analogous to those facing Forest Service Research, and relate this information to forestry research.	Hendee McFadden	Stanley Gessell, Univ. Washington
d. Understand factors affecting balance within the research program.	Gibbs Spada	Jay M. Hughes, Univ. Colorado
e. Propose procedures by which costs and benefits for research will be analyzed and presented in the future.	Shafer	R. S. Bond, Pennsylvania State Univ.
3. Revise portions of the Draft Documents and Summary Report relating to Research.	Shafer	
a. Extract and augment, with materials from the national/regional conference documents, the parts of the draft documents relating to Research.	Fasick	
b. Distribute the Research extract through Stations and Research Staffs and solicit comments from those people specifically interested in Research.	Fasick	
c. Provide revised and extended text relating to Research for the final RPA documents.	Fasick	

[1] Research managers who collected and analyzed available information and prepared reports. For their full names and affiliations, see chapter introductions.

[2] Members of Association of State College and University Forestry Research Organizations who reviewed and commented on Forest Service reports.

[3] Assistant Directors for Planning and Applications at Experiment Stations and Forest Products Laboratory.

Decisions About Research Programs

Many questions were put to managers of Forest Service Research as the status of natural resources was assessed and alternative programs were proposed. The larger questions related to how much funding was justified for research and to how fast or slow the funding was needed. Some other questions were: Why should programs start now rather than being deferred until the national economic situation eases? Why should the Federal Government, rather than States or industry, support forestry research? What should be the relative priority for funding between management of land and resources versus research to generate new technology for management in the future? What will be the payoffs from research that is proposed? When might benefits be expected?

Other Federal Research Agencies[2]

To help us shape our answers to these questions, we turned to other Federal research agencies facing identical questions. During a 2-week period, we questioned national leaders about budgetary planning, criteria for making decisions, establishment of priorities, and evaluation of programs in these 14 Federal agencies:

U.S. Department of Agriculture
- Economics, Statistics, and Cooperatives Service
- Office of Budget, Planning and Evaluation
- Science and Education Administration

U.S. Department of Commerce
- National Oceanic and Atmospheric Administration

U.S. Department of Defense
- Defense Advanced Research Projects Agency

U.S. Department of Energy

U.S. Department of Health and Human Services
- National Institutes of Health

U.S. Department of Interior
- Bureau of Land Management
- Fish and Wildlife Service
- Office of Water Research and Technology

Independent agencies
- Environmental Protection Agency
- National Aeronautics and Space Administration
- National Science Foundation
- Smithsonian Institution

We asked them how they have answered these and similar questions and how they decide about programs and funding for research. Our hopes for simple, direct answers and for precedents to follow were not realized. On the basis of this survey we concluded that . . .

- No precedents, examples, and guidelines can be transferred to the Forest Service for use in determining how resources should be committed to research in answer to such questions as "How much? How fast? Why now?"
- Criteria for developing and selecting research programs at the national level are many, complex, interactive, and intermingled with the planning process.
- As part of the broad Federal research community and total scientific community, Forest Service Research depends upon, and contributes to, the general body of scientific knowledge.
- To be of most use to society, Forest Service Research must have standing and credibility with its peers within and outside of the Federal scientific community.
- Forest Service Research has much in common with all other research agencies—especially U.S. Department of Agriculture's (USDA) Science and Education Administration (SEA)—but also has unique characteristics. No other agency contacted has our type of organizational structure or situation. Forest Service Research is unique in being a subpart of an operating agency. But it has a broad array of clients to serve. And the operating branches of the parent agency are only two of its many clients.
- Because of the unique characteristics of Forest Service Research—its broad mission, its many clients, and its interrelationships with the science community—research program size and growth should be related both to that of SEA and other research organizations, and to changes in the two other branches of the Forest Service: National Forest System (NFS) and State and Private Forestry (S&PF).
- Research agencies review and evaluate their programs for progress towards objectives, quality of science, and managerial effectiveness. Evaluations are difficult and lack standardization. The process of planning, selecting, and evaluating research programs is basically the same in all agencies. And the criteria are generally the same, differing only in specifics.

Given agency missions, specific congressional direction, and budget limitations, a research program is devised by negotiation among the "needs" as seen by the action program managers, other users, in-house research staff, and the outside scientific community. Constraints include budgets, ongoing commitments, the limits of the state-of-science, and acceptability of proposed programs to users, clients, or advisors.

Difference among agencies can be illustrated by comparing the National Science Foundation (NSF) and the Fish and Wildlife Service (F&WS), U.S. Department of Interior. NSF receives an appropriation for research, its mission is basic research, and its clients are members of the scientific community. Negotiation is among different disciplines of science. Research in the F&WS is funded internally (no budgetary line item for research); its mission is to improve the scientific basis for the F&WS programs; and its primary clients are F&WS

[2]The team responsible for the tasks contributing to this and the following two sections was led by R. Duane Lloyd (NE) and included John W. Koning, Jr. (FPL) and Max W. McFadden (PNW).

program managers. At the F&WS, research negotiates with action programs for its funds.

Forest Service Research is unique among Federal Research Organizations. It has separate appropriations. It has a broad mission ranging from applied to basic research. Its clientele is extremely diverse ranging from laymen to practitioners and other scientists. And it competes for funds with nonresearch activities.

The criteria commonly used for decisions about programs and budgets throughout Federal research are:

- Direction from Congress:
  - —Organic Acts
  - —Appropriations Acts
  - —Special Acts (e.g., Endangered Species)
  - —Budget limits and authorities
- Direction from the Administration:
  - —General policy (e.g., anti-inflation or constrained employment)
  - —Departmental and agency objectives
- Research needs, as perceived by:
  - —Administrators and managers of action programs
  - —Other clients
  - —Scientists
- Opportunities to advance science
- Limitations of the state-of-science.

Typically, research agencies review and evaluate their programs regularly. Such evaluation includes reviews by management, by teams of scientists from outside and by advisory groups. Reviews typically check (a) actual progress and accomplishment against objectives and targets, (b) scientific quality, and (c) management effectiveness.

Evaluations of research programs are difficult—no standard methodologies or criteria exist. The greater the potential for scientific payoff, the more difficult the evaluation, since the output is addition to knowledge, rather than a product for the market. No agency has developed the capability to evaluate research in relation to planned progress when such progress depends on key breakthroughs in present knowledge. The judgment of other qualified research scientists is critically important. For applied research, the judgments of practitioners also is important in evaluations. Some agencies, such as the National Institutes of Health (NIH), use extensive management information systems in evaluations. The NIH is also currently exploring the use of bibliometric (citation analysis) techniques as an evaluation tool. In most agencies, prior accomplishment by research and "track record" are among the criteria used in justifying new programs.

Federal Support for Research and Development

Why should the public, through the Congress and State legislatures, fund and support scientific research and development (R&D)? Why should not private industry do it all? If government should pay for some and industry should pay for some, who should pay for which kinds?

Answers to these questions have evolved and become a part of American public policy over the years. Administrations in government and industry generally agree that responsibility for research and development can be divided, as follows:

Government	*Industry*
Basic and applied research.	Applied research and development.
Inappropriable results cannot be captured or appropriated for exclusive use.	Appropriable results can be captured and exploited in the market place.
Adds to the general body of scientific knowledge and "knowledge capital."	Applies knowledge for "practical" purposes.
Contributes to broad social objectives.	Contributes to particular commercial objectives.
Contributes to long-term economic growth and productivity.	Contributes to short-term economic growth.
Benefits future generations, natural resource and environmental conservation.	Benefits present consumers and present use of resources.

Both government and industry recognize scientific research as a form of capital investment necessary to economic growth and viability (Healy 1978).

President Jimmy Carter (1979c) recently delivered a message to the Congress calling for "its commitment to nonpartisan investment in science and technology for our future." Said the President:

> . . . new technologies can aid in the solution of many of our Nation's problems. These technologies in turn depend upon a fund of knowledge derived from basic research. The Federal government should therefore increase its support both for basic research and, where appropriate, for the application of new technologies.
>
> . . . . .
>
> The Federal Government's support of research and development is critical to the overall advance of science and technology. Federal responsibility lies in three major categories:
>
> 1. The largest fraction of the Federal investment serves the Government's direct needs and responsibilities, such as defense, space, and air traffic control.
>
> 2. The Federal Government undertakes research and development where there is a national need to accelerate the rate of development of new technologies in the private sector. This is especially true when the risk is great or the costs inordinately high, such as with many aspects of energy and transporta-

tion. However, we look to private industry to finance research and development activities having near-term commercial payoff. Industry is most sensitive to the marketplace, to the benefits of competition, and to the commercialization of new technologies . . .

3. The Federal Government supports basic research to meet broad economic and social needs. Basic research is a quest for new knowledge. Research to advance scientific understanding—in astronomy, geology, chemistry, the behavioral and social sciences, and other areas—expresses our innate curiosity about ourselves and the universe. But basic research also is the forerunner of new inventions, advances in health care, nutrition and *agricultural production*, many *new products of commerce*, and *new technologies for* defense, space, *energy, and environmental protection*. (emphasis added)

. . . . .

I would ask the Congress, in acting on agency budgets, to be aware of the interrelationships and the importance of each agency's contribution to a comprehensive, national program in support of science and technology.

. . . . .

During this century, the United States has built a system of industrial, university, and government research laboratories that is unparalleled in the world. We have the national capacity to generate new basic knowledge, and to apply this knowledge to a broad range of problems . . . my Administration is marshalling science and technology in terms of six domestic objectives:

—Stimulating innovation in industry to sustain economic growth and improve productivity;

—meeting our energy, *natural resource*, and food needs;

—promoting better health for all;

—*improving the regulatory process*;

—expanding the beneficial use of space; and

—*understanding the forces of nature*, natural disasters, and *changes induced by man*. (emphasis added)

. . . . .

Equally as important as the substance of our science and technologypolicies is our strategy for managing it and ensuring its vitality. This task is a challenging one because of the diversity of the participants—business and industry, universities, the Federal agencies, government at all levels, and the public. Each sector has distinct goals and objectives and special institutional qualities. Yet each can work with the others in a lively process of cooperation, so long as some independence is assured and our policies are adaptable to each.

Seven years earlier, President Richard Nixon (1972a) summarized the situation this way:

In general, I believe it is appropriate for the Federal Government to encourage private research and development to the extent that the market mechanism is not effective in bringing needed innovations into use. This can happen in a number of circumstances. For example, the sheer size of some developmental projects is beyond the reach of private firms, particularly in industries which are fragmented into many small companies. In other cases, the benefits of projects cannot be captured by private institutions, even though they may be very significant for the whole of society. In still other cases, the risks of certain projects, while acceptable to society as a whole, are excessive for individual companies.

President Nixon's Economic Report to the Congress (1972b) included an extensive section on "Rationale for Government Involvement":

. . . Government has an appropriate role in R&D even when its results will not be incorporated in Government purchases, because private firms would underinvest in R&D for goods normally purchased by the private sector. Although an investment in R&D may produce benefits exceeding its costs from the viewpoint of society as a whole, a firm considering the investment may not be able to translate enough of these benefits into profits on its own products to justify the investment. This is because the knowledge which is the main product of R&D can usually be readily acquired by others who will compete away at least part of the benefits from the original developer.

This is particularly true of basic research, where the output frequently occurs in the first instance not as a marketable product, but rather as an advance in basic knowledge that can subsequently be used in applied research and development by a wide and often unforeseeable range of firms.

One way to encourage more spending on R&D for private goods is, of course, by direct funding. When this approach is followed, it is sensible for Government's share of total expenditures to be greatest for basic research and to decline at subsequent stages. The difference between social and private benefits is largest for basic research and diminishes when investments begin to provide returns that can be obtained through private markets. Increasingly, it is recognized, however, that even at the developmental, demonstration, and diffusion stages of innovation, social benefits may exceed private benefits.

When private action or patent protection is not sufficient to achieve scale economies or capture external benefits, direct Government support for R&D may be appropriate. This would be especially true in an established industry with many small firms.

Under such conditions, an individual firm may have little incentive to undertake its own research or to participate in an ongoing venture in R&D conducted jointly by a group of these firms; it would have difficulties capturing the benefits of its own efforts, and the benefits of their efforts in agricultural research, for instance, started because individual farms were too small to undertake their own research and lacked the incentives and institutions to support joint arrangements.

. . . benefits are often widely diffused in society and thus difficult to measure. Comprehensive analysis is further hindered because the transformation of research into new knowledge and of new knowledge into public and private innovations and workable technologies is not yet adequately understood. Until better analysis is available to show the benefits, costs, and processes associated with R&D, informed judgment will continue to be the major element in shaping public policy.

Public Investment

Analyses of the issue of how much the public should invest in government research have shown us the *direction* of needed change—but not a specific quantity. Industry and government tend to underinvest, and thus more spending on research and development would yield additional benefits.

Mansfield and others (1975) have shown that the marginal rate of return from investments in R&D has been "very high." They also noted that industry generally tends to underinvest and underinvestment is greatest at the more basic end of the spectrum.

Internal rates of return on R&D, at the industry level, have been measured at 30 to 50 percent in chemicals; 15 percent in food, apparel and furniture; and 35 to 170 percent in agriculture (Lederman 1978).

Although no studies have shown precisely how much public funds should be committed to natural resources research, all indications are that it should be more than now, and that returns on investment are high enough to justify substantial increases.

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Table 2—*Four criteria used to evaluate alternative research programs*

Indicator/units of measure	Standard	Data source
	Response to needs	
1. Expressions of national needs—problems or targets for research 2. Expressions of regional needs—problems or targets for research 3. Special research programs—targets identified	Applies to all three indicators: Problems or targets beiing addressed Usable results being produced Targets achieved	1. National planning documents (including assessment) 2. Regional planning documents, research needs—research response 3. Special research analyses
	Contributions to productivity and other returns	
1. Research work unit accomplishment	1. Supervisor and peer acceptance of accomplishments in attainment report	1. Annual research work unit reports
2. Innovations produced	2. Acceptance by research managers and peers	2. Annual reports from R&D programs, special reports
3. Internal rates of return based on costs and quantifiable benefits	3. Favorable internal rates of return	3. Hindsight analyses and other reports
4. Costs and nonquantifiable benefits	4. Acceptable costs related to expected benefits, physical/biological improvements, social improvements, or environmental improvements	4. Hindsight analyses and other reports
	Response to national policy	
1. National pronouncements 2. Forestry research leadership	1. Responsiveness to national direction 2. Fulfilling leadership role called for in 1978 legislation	1 and 2. Executive Branch messages and orders; Congressional oversight and legislative intent; Joint Council and Users Advisory Board of USDA; National Academy of Sciences, and others
	Relation to historical trends	
1. Proportion of Federal R&D budgets	1. Budget trends	1. National Science Foundation
2. Proportion of USDA Research budgets	2. Trends 1967 to present	2. USDA agencies
3. Proportion of Forest Service budget	3. Trends 1954 to present	3. Appropriation records

Criteria for Evaluating Programs[3]

One primary output from our effort was the first set of criteria for evaluating research program alternatives in the Forest Service (table 2). These criteria were developed from meetings with representatives of other Federal research agencies, deliberations over questions posed in the RPA process, and compilation of available information from a wide variety of sources. Four criteria are proposed.

Response to Needs

Needs, desires, and wants are expressed nationally, regionally, or through special efforts. They reflect the nonexistence, inadequacy, or unavailablilty of technology to solve problems. The needs to which public resources should be directed must be segregated from those that are the responsibility of the private sector.

[3]The individual responsible for the task contributing to this section was Denver P. Burns (NC).

Contribution to Productivity and Other Returns

Research programs are expected to contribute in the future more or less as they have in the past; therefore, hindsight analysis can be useful in predicting future contributions from research. Research often generates technology resulting in quantifiable benefits. In such cases, calculation of benefit/cost relationships and of internal rates of return on investments is relatively straightforward and simple. More often, research results in nonquantifiable benefits. Currently, we cannot relate such benefits to the costs of generating that technology.

Response to National Policies

The Executive Branch of the Federal Government, the Congress, and nationally and internationally significant organizations continually influence the evolution of national policies related to research. To determine our current national policy with respect to forestry research is difficult at best. To anticipate how that policy may change in the short and long-range future is almost impossible, but nevertheless is required.

Relation to Historical Trends

The course of research should not be changed drastically, for sustained, high quality output requires continuity and long duration for most research programs. Charting a future course for research should not be done without a backward glance or without recognition of what has happened and will happen to related programs.

Use of these four criteria to evaluate alternative research programs in the Forest Service should pose no difficulty because they have been used singly or in combination at various times in various parts and levels of government research programs. The criteria, together with indicators and units of measures, standards, and sources of data, have been displayed for and accepted by decisionmakers in the Forest Service. They provide the basis for the rest of this report.

Response to Needs

Assessment of Needs and Alternative Programs[4]

The first step in the process was to identify needs for research. The second step was to see how the proposed and alternative programs would meet those needs. The third step was to identify factors that must be considered in any decision about research programs.

Broad Needs for Research

The Nation's needs for research are generated by legislative mandates, by expressions of users of technology, and by scientists actively working on the problem or subject area. Needs for research, as identified by all of these sources, were considered.

The legislative mandate for planning and cooperation for research stems from the RPA and other recent Acts of Congress. The RPA did not require an assessment of the state of forestry technology, as it did require an assessment of the state of forestry resources. Had we been required to assess the state of forestry technology, we would have been in a better position to recommend a research program. Title XIV of the Food and Agriculture Act of 1977 mandated cooperation in analyzing the needs and planning for research programs, including forestry in all of its aspects. The Renewable Resources Research Act of 1978 provides the basic authority for forest and rangeland research in the United States.

Broad research needs have been identified through several processes in recent years. Of greatest importance were the four regional planning conferences held during summer 1977. Representatives of users of research identified 2013 general and specific problems and ranked them as to priority. Then delegates from the regions went to a National Forestry Research Planning Conference early in 1978 to nominate and to rate, in priority, 51 generalized problems for national attention.

As a result of the Food and Agriculture Act of 1977, the USDA, in cooperation with the State Agricultural Experiment Stations (SAES), also has established a regional and national planning system. A national research planning committee coordinates the efforts of four regional planning committees. Under the national and regional planning committees, research program groups have been identifying the needs in forestry research planning under the RPA has involved primarily the Forest Service, but to some extent also its cooperators in the forestry schools and in the SAES. Legislation and the expression of legislative intent through oversight hearings and laws have been strong indicators of needs for Research to provide new technology. National policy, as enunciated by the President and other officials of the Executive Branch, the Congress, and national organizations have a strong effect on planning for research.

Specific needs for research were identified in several ways. Resource managers, particularly those employed in the Federal and State Governments and who have responsibilities for vast areas of land or significant resources, quickly brought to our attention their needs for technology and the problems they must solve. Consultants and advisors to those who own, but may not manage, their own lands and resources also called needs for research to our attention. Industrial, private interest, and user groups identified needs from their perspective, as did scientists and academicians. The result is a broad spectrum of identified needs greatly exceeding current or anticipated capabilities to work on the problems.

Special Needs for Research

The identification of problems needing research is only a partial step in laying out the needs for a research program. Required also are plans detailing the research approach, scope of the problem, duration and timing of the expected research effort, skills and special talents needed, and financial resources required to solve the problems.

Many of these plans, based on needs expressed by seasoned practitioners and knowledgeable scientists, would utilize the proven organization structure of R&D programs to resolve the problems. Twenty-one special research plans produced during recent years provide this kind of detailed planning:

RPA element	*Plan*
Recreation and Wilderness	Dispersed Recreation Development Recreation
Wildlife and Fish	Threatened and Endangered Species Anadromous Fish Wildlife and Fish Habitat
Range	Management of Range Resources
Timber	Eastern Hardwoods Timber Management Forest Products Utilization and Improvement Forest Engineering
Water	Riparian Habitat and In-Stream Flow Prevention and Alleviation of Pollution Snow Management
Minerals	Minimizing Environmental Damage from Surface Mining
Human and Community Development	Urban Forestry

[4]The team responsible for the task contributing to this section was led by Denver P. Burns (NC) and included R. V. Smyth (NC), Nelson S. Loftus, Jr. (SO), Eldon M. Estep (PNW), Glenn A. Cooper (PNW), and Albert N. Foulger (NE).

Protection	Fire Effects Fire Prevention and Control Minimizing Insect Damage Minimizing Disease Damage
Lands	Arid Lands Wildlands Planning
All Elements	Basic Research Competitive Grants International Forestry

Because basic research does not have a spokesperson or general advocate, it is often overlooked. The role of basic research in providing for future breakthroughs in benefits to society is, however, becoming more widely recognized. Recent planning efforts have identified several areas of basic research closely related to renewable natural resources that need more attention. These efforts could be the basis for the competitive grants programs authorized by the Renewable Resources Research Act of 1978. Therefore, basic research was placed among the special plans.

Another neglected area of forestry research involves scientists in other countries. The Renewable Resources Research Act of 1978 authorizes international forestry research to augment the investigative effort on topics vital to forest and rangeland management and resources in the United States. Such research would have a secondary benefit in strengthening the research capabilities in lesser developed countries. Numerous areas of concern, both to scientists and practitioners in the United States and to their counterparts in other countries, have been identified. These can be addressed directly, through a variety of bilateral programs, through the United National organizations and their programs, or through other international organizations, such as the International Union of Forestry Research Organizations. Funding has not yet been provided for such research, so it was added to the special research plans.

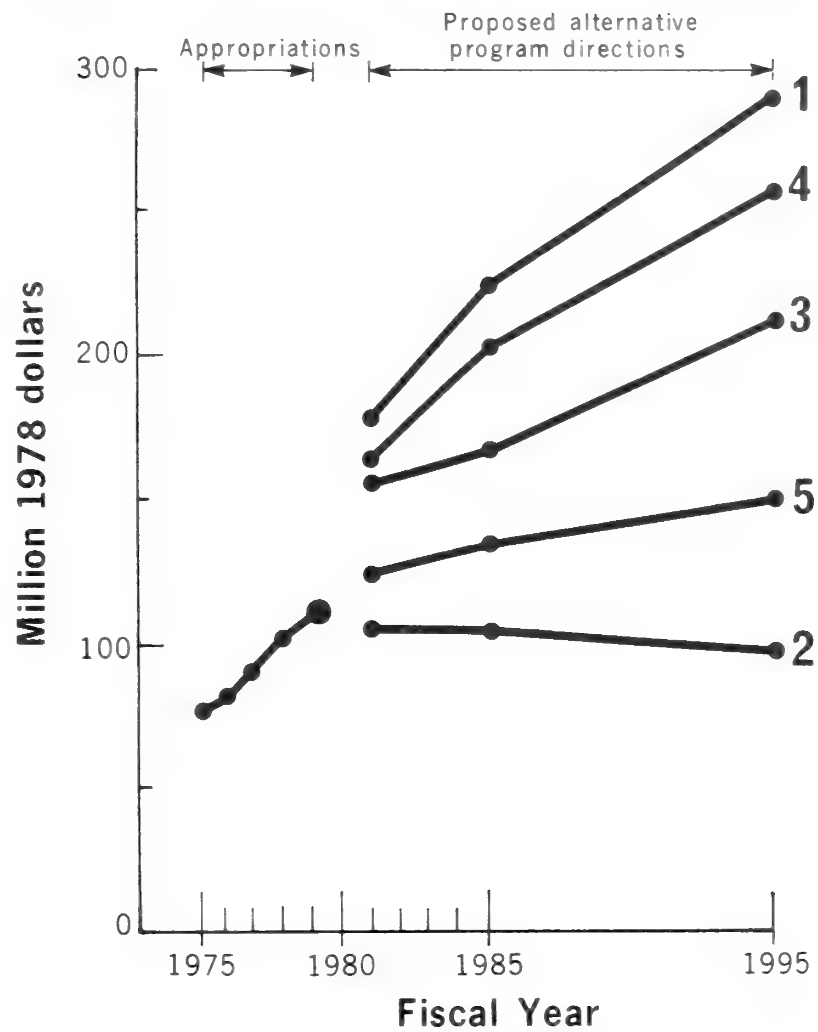
Needs in Relation to Alternative Programs

The draft alternative programs for research were projected in 1978 without consideration of the needs identified either in the regional/national planning process or in the special research plans. The RPA funding levels for research decided upon in 1975 were simply projected ahead to the period 1981 to 1985 (fig. 1). In March 1979, the Forest Service released for review its report on "Alternative Program Directions, 1981–2030." This document sets forth five future alternative program directions (APD)—each with a proposed level of funding. No effort had been made previously to determine how well the five APD's meet the needs identified by the regional/national conferences and the special research planning efforts.

The nine Forest Service Experiment Stations, eight regional Stations plus the national Forest Products Laboratory, were asked to determine how well the five APD's assigned to them would meet the needs identified in the conferences. The Stations used 15 lists of the needs for research that were assigned highest priority by users at the regional conferences. Only 1,016 of the highest priority problems—not all 2,013 problems—were included in this evaluation. Stations were asked to evaluate whether each APD would enable their scientists either to produce some usable results or at least to have research underway in the period 1981 to 1985. Usable results meant "for use by others than the scientists who generated them." Results would not necessarily be used by practitioners or would not necessarily solve the problem that had been listed, only that some results would be usable. Stations also were asked to identify those problems that would not be addressed at all.

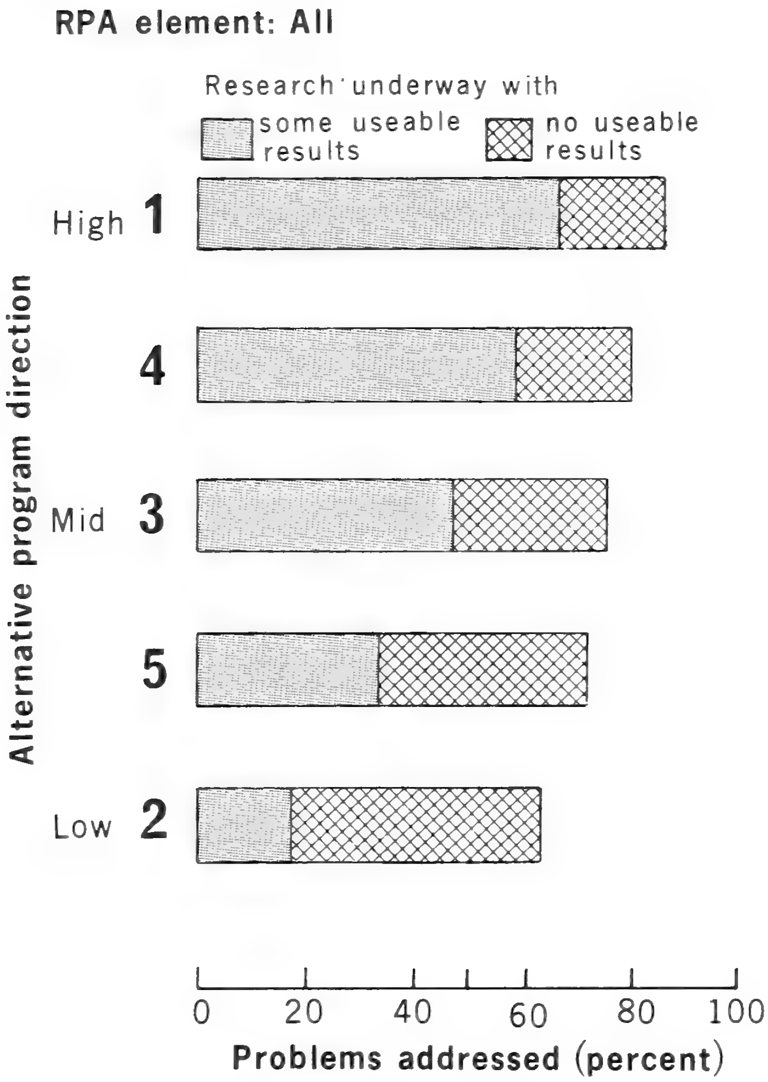
A comparison of research proposed by all Stations in all RPA elements (fig. 2) shows that the lowest level program, APD 2, would be totally unresponsive to the needs identified in the

Figure 1



Appropriations for Forest Service Research, 1975–1979, and projected funding, by five alternative program directions, 1980–1995.

Figure 2



Five alternative program directions for Forest Service Research would address different proportions of regional problems.

regional conferences. APD 2 would only produce usable results for 17 percent of the identified problems. The mid-level program, APD 3, would provide some usable results for 47 percent of the problems, but would address few new problems. The highest level program, APD 1, would be responsive to the needs identified at the regional conferences because research would be underway on 85 percent of the needs.

At each of these five APD levels, responsiveness of research among the elements of RPA is seriously imbalanced (fig. 2). For example, the timber element would be relatively well funded, but the range, wildlife, and fish elements would be poorly funded. This difference reflects historical and current funding of existing programs, for the projections for future programs were based upon past funding rather than upon expressed needs.

Only half of the identified problems were included in this analysis. How the Stations would similarly relate to the needed research that was judged to be essential, but of lower priority, is unknown.

After considering the regional needs for research, the Stations considered the 51 problems identified at the national planning conference (fig. 3). This analysis indicates that the lowest level program, APD 2, would provide usable results for 28 percent of the national problems. The mid-level program, APD 3, would provide usable results on 59 percent of the national problems. The highest level program, APD 1, would provide usable results for 78 percent of the national problems. Thus, the APD's seem to be relatively as responsive nationally as they were regionally.

At the national level, as at the regional level, severe imbalance is reflected in the approach to problems in different elements. For example, APD 2 would only provide usable results for slightly more than 10 percent of the national problems in the recreation, wilderness, and human and community development elements; whereas, it would provide usable results for nearly 40 percent of the problems in the wildlife, fish, and range elements. Similarily, the highest funding for APD 1 would provide usable results for more than 80 percent of three of the elements, but only on 65 percent of the problems in the recreation, wilderness, and human and community development elements. Thus, many national problems in these elements would not even be addressed at the highest funding level.

In summary, data provided by the Stations would indicate that funding for research on regional problems at the lowest level, APD 2, would mean:

- Usable results would be produced in only 17 percent of the problems;
- Research would be underway with no results for 45 percent of the problems; and
- 38 percent of the problems would not be investigated.

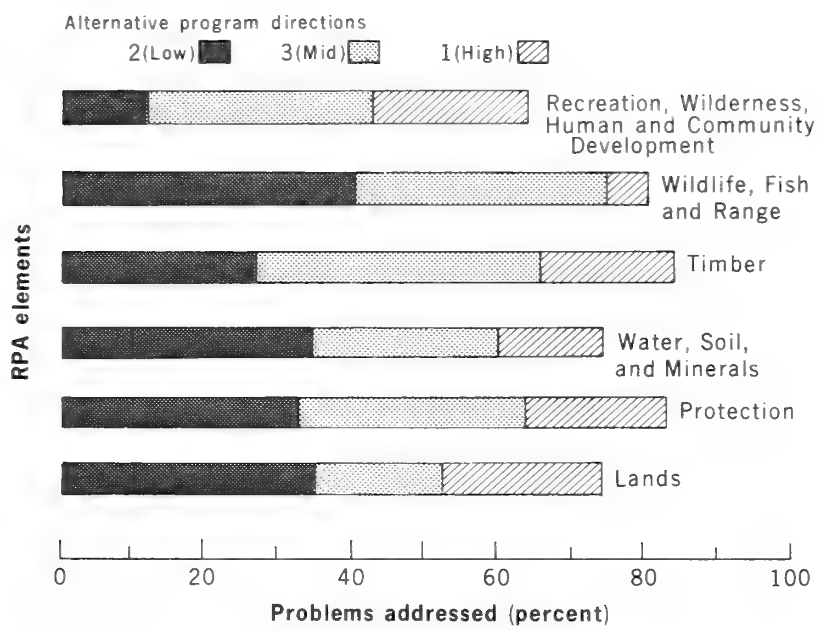
Funding at the mid-level, APD 3, would mean:

- Usable results would be produced for 47 percent of the problems;
- Research would be underway, but with no usable results, for 28 percent of the problems; and
- About 25 percent of the problems would not be investigated.

Funding at the highest funding level, APD 1, would mean:

- Usable results would be produced for 65 percent of the problems; and
- Research would be underway with no usable results for 20 percent of the problems.

Figure 3



Three of the alternative program directions for Forest Service Research would address different proportions of national problems.

For the national problems, APD 2 would provide usable results for only 28 percent of the problems; APD 3—59 percent of the problems; and APD 1—78 percent of the problems.

The regional and national conferences, of necessity, did not consider special needs for basic research or for international forestry. Both topics are of growing national concern. President Carter (1979a), in his budget message for FY 1980, called for a strengthening of support for basic research. Philip Handler (1979), President of the National Academy of Sciences, listed six environmental issues among those needing priority:

- Cleansing of the atmosphere by forests and other vegetation;
- Effects of acid precipitation on soils, lakes and streams, and natural food chains;
- Fate of volatile pesticides and other chemicals used in forestry and their effects on humans and the environment;
- Water resource issues;
- Effects of nonpoint pollution; and
- Substances and processes involved in atmosphere-biosphere exchange.

Some other topics commonly listed as needing basic research and important to forestry are biological nitrogen fixing, photosynthesis, genetic engineering, and control of growth and reproduction.

To attack these and other high priority topics would require an expanded program of basic research topics critical to renewable natural resources would seem to deserve funding at least at the level of $5 million in FY 1981, expanded to $20 million by FY 1995. Such an expansion of basic research might be through competitive grants to the best qualified investigators.

The needs for more research in international forestry are becoming matters of national concern. In 1978, the Congress authorized agencies to conduct such research. In his environmental message to the Congress, President Carter (1979c) directed Federal agencies to "place greater emphasis on world forest issues in their budget and program planning. . . . Nearly all of the world's forest loss is occurring in or near the tropics," said the President, and "environmental damage from deforestation can be severe—even irreversible." The Forest Service has recognized these needs and opportunities for research in other countries. Funds needed for international forestry research are estimated at $1.6 million in FY 1981 and $6.9 million in FY 1985.

The special research plans produced during recent years have not been disaggregated to Stations. Thus, the Stations were unable to relate, within alternative programs assigned to them, to the research called for in these special plans. Therefore, we analyzed at the national level parts of these plans that would be provided at the level of APD 5. Then we estimated the additional funds available under APD 1 that would be used for these plans. Finally, the still unfunded portion of the plans was estimated as a cost over that provided by the highest proposed level, APD 1. The outcome of this analysis (table 3), indicates at the level of APD 5 that an additional $23.7 million, a total of $147.9 million, would be needed to provide for those plans judged to be of highest or of medium priority. At the mid-level of APD 3 the additional needs for these plans is $33.1 million, a total of $186.8 million. At the highest level, APD 1, an additional $102.4 million would be required to fund these plans, a total of $280.9 million. These alternative funding levels for research might be labeled 5+, 3+, 1+, etc. They substantially change the expression of research needs and of the alternative funding levels needed for research.

Clients for Research[5]

Decisions about research programs should be made with some understanding of the great number and diversity of clients for forestry research in order to appreciate the many demands for knowledge and methodology to which research must respond. Individual research users represent a continuum including resource professionals, private landowners,

[5]The individual responsible for the task contributing to this section was Richard L. Hubbard (PSW) assisted by Walter A. Hough (SE).

Table 3—*Special research plans available for planning, priorities for funding, and suggested costs in 1981*

Resources Planning Act element	Research plan	Priority by Alternative Program Direction level[1]					Suggested 1981 costs		
		2	5	3	4	1	Base + increase to level 5	Increase from levels 5 to 1	Increase beyond level 1
							——— *Dollars (thousands)* ———		
Recreation and wilderness	Dispersed recreation	L	L	M	H	H	2,618	1,050	1,875
	Developed recreation	L	L	M	H	H	0	0	500
Wildlife and fish	Threatened and endangered species	M	H	H	H	H	2,413	1,043	2,930
	Anadromous fish	L	M	M	M	H	1,484	0	1,485
	Wildlife and fish habitat	L	M	M	M	H	2,216	775	3,300
Range	Management of range resources	L	L	M	L	H	1,781	2,120	5,150
Timber	Eastern hardwoods	L	M	M	H	H	[2]15,336	[2]9,943	[2]5,625
	Timber management	L	M	M	L	H	946	400	3,400
	Forest products utilization improvement	L	M	M	L	H	3,600	1,000	7,300
	Forest engineering	L	M	M	L	H	2,376	1,409	1,200
Water	Riparian habitat and instreamflow	L	L	L	H	H	1,245	717	1,100
	Prevention and alleviation of pollution	L	L	M	H	H	6,000	2,662	1,350
	Snow management	L	L	M	M	H	886	700	700
Minerals	Minimizing environmental damage from surface mining	L	L	L	H	H	2,719	350	3,975
Human and community development	Urban forestry	L	L	M	H	H	2,299	1,593	10,760
Protection	Fire effects	L	L	M	L	H	3,075	1,255	2,950
	Fire prevention and control	L	M	M	L	H	4,224	932	6,200
	Minimizing insect damage	L	M	M	M	H	5,548	3,350	8,335
	Minimizing disease damage	L	M	M	M	H	1,206	530	3,571
Lands	Arid lands	L	L	L	M	H	583	2,488	1,835
	Wildlands planning	L	L	L	L	H	2,730	519	1,915
All	International forestry	L	M	M	M	H	300	1,300	0
	Basic research (competitive grants)	L	M	M	M	H	0	0	5,000
Suggested annual funding (million dollars)		1.0	23.7	33.1	43.4	102.4			

[1] L = low; M = medium; H = high.

[2] Funds needed by the Forest Products Laboratory are not included.

Table 4—*Permanent full-time employees in resource-related disciplines, by Federal agencies, 1977*

Discipline	Five agencies[1]	Federal
Biological Sciences:		
Agronomists	70	340
Botanists	47	144
Biologists, general	998	3,811
Biologists, fisheries	641	1,154
Biologists, wildlife	1,055	1,055
Entomologists	165	758
Environmental specialists	166	681
Fish and wildlife administrators	104	198
Fish hatchery managers	23	34
Foresters	5,195	5,395
Geneticists	40	220
Histologists	1	10
Microbiologists	27	1,659
Museum curators	59	216
Nutritionists	1	100
Pathologists, plant	95	319
Physiologists, animal	17	369
Physiologists, plant	44	255
Range managers	1,093	1,093
Refuge managers	462	462
Zoologists	31	124
Total	10,334	18,397
Physical Sciences:		
Cartographers	143	2,853
Chemists and chemical engineers	94	1,500
Forest product technicians	113	122
Geologists	382	2,238
Hydrologists	247	1,802
Meteorologists	22	2,127
Physical scientists	34	200
Soil scientists and conservationists	6,410	6,410
Total	7,445	17,252
Social Sciences:		
Anthropologists	3	62
Archeologists	262	283
Economists	213	1,000
Geographers	17	172
Historians	64	500
Recreation specialists	298	1,000
Sociologists	23	250
Psychologists	4	100
Total	884	3,367
Engineering:		
Architects	168	1,589
Engineers (other than chemical)	2,621	4,000
Landscape architects	373	607
Total	3,162	6,196
Mathematics:		
Mathematicians and statisticians	63	300
Operation research analysts	20	2,902
Total	83	3,202
Grand totals	21,908	48,414

[1] Forest Service, Bureau of Land Management, Fish and Wildlife Service, Soil Conservation Service, and National Park Service.

resource-dependent industries, educators and students, legislators, citizens groups, homeowners, and the general public. Each group has a different tie to and need for outputs from forestry research. To estimate the number and diversity of all users is impossible, but we tried to estimate the number and diversity of professionals who depend upon Forest Service Research.

Professional users in the Federal Government are numerous and extremely diverse. About 40 Federal agencies rely, at least to some extent, on Forest Service Research:

U.S. Department of Agriculture
- Forest Service
  - National Forest System
  - State and Private Forestry
- Agricultural Stabilization and Conservation Service
- Animal and Plant Health Inspection Service
- Farmers Home Administration
- Rural Electrification Administration
- Science and Education Administration
- Soil Conservation Service

U.S. Department of Interior
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Reclamation
- Fish and Wildlife Service
- Heritage Conservation and Recreation Service
- National Park Service
- Office of Surface Mining Reclamation and Enforcement
- Office of Territorial Affairs

U.S. Department of Commerce
- Bureau of Domestic Business Development
- Economic Development Administration
- Fire Administration
- National Bureau of Standards
- National Oceanic and Atmospheric Administration

U.S. Department of Defense
- Air Force
- Army
- Navy

U.S. Department of Energy

U.S. Department of Housing and Urban Development
- Federal Housing Administration

U.S. Department of Health and Human Services

U.S. Department of Transportation
- Federal Highway Administration

U.S. Environmental Protection Agency

U.S. National Aeronautics and Space Administration

Tennessee Valley Authority

Five of the major Federal resource agencies (Forest Service, Bureau of Land Management, Fish and Wildlife Service, National Park Service, and Soil Conservation Service) employ professionals trained in 42 broad disciplines (table 4). This complex staffing reflects the multiple goals of modern natural

resource management. These five agencies, comprising part of the direct audience for Forest Service Research, employ about 22,000 resource-oriented professionals. Another 26,000 professionals, employed by 35 more Federal agencies, rely at least to some extent on Forest Service Research (table 5). Therefore, Federal professionals who would depend upon publicly supported forestry research total about 48,400. Data from professional societies indicate that about 25 percent of their members are employed by the Federal Government (table 6). The total number of resource professionals in the Nation who would be concerned about Forest Service is estimated to be about 200,000.

The results of forestry research are also used widely by State, county, and local agencies, and by universities and colleges. Managers, academicians, scientists, and other professionals depend heavily on such results for coordination of research programs, for inclusion of findings into training and education, and for growth of disciplines.

The general public includes direct and indirect users of forestry research. Nearly everyone uses products from wildlands or benefits from amenities of wildlands. Some of the public benefits directly, as from publications related to enjoying wildlife, using wood in construction, protecting wood in use, and protecting shade trees. Innumerable students and their teachers depend upon research to explain their fields of study and to push back their frontiers of knowledge.

How many people actually want the results of research? One measure of who uses outputs from forestry research was obtained by analyzing mailing lists of Forest Service Experiment Stations (table 7). The number of individuals, agencies, firms, and others exceed 100,000 nationally. This total includes some redundancy since many addressees are on two or more mailing lists. But often more than one person benefits from a single document. Our "guesstimate" is that we may reach 70,000 individuals each year by mail. Individuals of unknown affiliation account for more than 35 percent of the mailing addresses; colleges and universities for nearly 14 percent; industries and the private sector for 22 percent; surprisingly, mailings within the Forest Service constitute only 6 percent of the total, but we know that many persons are reached at each address. More than 8 percent of the mailing goes to other countries, indicating the international interest in Forest Service research.

We estimate that the minimum number of direct contacts with users by Forest Service Research during FY's 1977 and 1978 accumulated to about 135,000. About 70,000 received publications, and about 65,000 were reached by other means such as seminars, training sessions, and individual consultations. In 1975, about 1,552 scientists were employed full-time in forestry research by the Forest Service, universities, and colleges. Each scientist serves an average of about 90 to 160 professional users of forestry research, and an untold number of users outside of professional categories.

Table 5—*Distribution among Federal agencies of permanent full-time employees in resource-related disciplines, 1977*

Disciplines	Federal total	Forest Service	BLM SCS NPS F&WS[1]	Other agencies
	Thousands			
Biological Sciences:	18.4	5.67	4.66	8.06
Foresters	5.4	4.67	0.52	0.20
Biologists	6.0	0.32	2.37	6.01
Range managers	1.1	0.30	0.81	—
Others (15)	5.9	0.68	0.96	1.85
Social Sciences:	3.4	0.07	0.81	2.48
Recreationists	1.0	—	0.30	0.70
Economists	1.0	0.04	0.18	0.78
Others (6)	1.4	0.03	0.33	1.00
Physical Sciences:	17.3	0.68	6.77	9.81
Hydrologists	1.8	0.15	0.09	1.56
Geologists	2.2	0.08	0.30	1.86
Soil scientists	6.4	0.21	6.19	—
Forest product technologists	0.1	0.11	—	0.01
Chemists and chemical engineers	1.5	0.05	0.04	1.41
Others (3)	5.3	0.08	0.15	4.97
Engineering:	6.2	1.28	1.88	3.03
Architects	1.6	0.02	0.14	1.42
Engineers (nonchemical)	4.0	1.07	1.55	1.38
Landscape architects	0.6	0.19	0.18	0.23
Mathematicians and operations research analysts	3.2	0.06	0.02	3.12
Totals	48.4	7.76	14.15	26.51

[1] Bureau of Land Management, Soil Conservation Service, National Park Service, Fish and Wildlife Service.

Table 6—*Employers of professionals in resource-related disciplines, 1979*[1]

Employers	Foresters (includes entomologists and pathologists)	Wildlife biologists	Range managers	Civil engineers (interested in resource research)	Wood technologists	Fishery biologists
	Percent					
Federal	27	14	43	16	3	14
Private	25	4	14	25	74	15
State	13	43	10	13	1	37
County and municipal	1	3	—	25	—	—
College and university	10	7	10	3	3	13
Consulting or self-employed	6	1	3	1	1	1
Other (including students and retired)	18	28	20	17	18	20
Totals	100	100	100	100	100	100

[1] As estimated by professional societies.

Table 7—*Recipients of mailings from Forest Service Experiment Stations in different geographic areas, and from Forest Products Laboratory*

Recipients	Experiment Stations covering . . . Pacific Coast	Rocky Mountains and Great Plains	Northern	Southern	Forest Products Laboratory	Total
	Percent					
Libraries and academia	20.0	26.3	15.3	14.7	15.1	16.5
Forest Service	8.8	11.0	3.3	2.6	9.0	6.0
Other Federal and international agencies	6.6	15.2	2.7	3.2	6.6	5.4
State, county and municipal agencies	4.4	8.0	14.1	4.6	—	5.4
Industry, trades, and media	9.5	8.2	18.1	19.0	41.9	23.0
Individuals						
In USA	35.8	30.0	29.7	46.8	27.4	35.4
Outside	14.9	1.3	16.8	9.1	—	8.3
Totals	100.0	100.0	100.0	100.0	100.0	100.0
	Number					
Addressees	13,727	7,676	19,769	33,086	28,040	102,298

Contributions to Productivity and Other Returns

Research-and-Development Productivity[6]

The rate of growth in productivity in the United States has fallen off—a distressing development in light of the increased productivity of economies of other developed nations. That technology has a significant, positive effect on productivity cannot be questioned. National, sectorial, and industrial analyses repeatedly have demonstrated the contribution of R&D to improving productivity.

President Carter (1979a), in his budget message to the Congress, noted that "Higher productivity gains (from basic research) in the future, moreover, will make an important contribution to reducing inflation."

From 1948 through 1966, the rate of growth in productivity in the private business economy was approximately constant at 3.3 percent per year. However, since 1966, the growth rate has substantially decreased. This decrease results from a number of factors, such as the relationships of labor and capital to the economy, the changing structure of our work force in terms of age and sex, economic regulations, and environmental concerns. However, the combined effect does not explain reduced productivity. Some have suggested that the decline in investment in R&D may be a significant cause of reduced productivity. The evidence lies in the coincidence between the diminishing ratio of R&D expenditures to total output and the decline in productivity.

According to Lederman (1971), "all available evidence indicates that R&D is an important contribution to economic growth and productivity. Research to date seeking to measure this relationship (at the level of the firm, industry, and the whole economy) points in a single direction—the contribution of R&D to economic growth/productivity is positive, significant, and high."

The decline in productivity in the United States contrasts sharply with growth in productivity in other developed countries (fig. 4). Since 1960, relative gain in productivity in the United States has been smaller than that in three other major industrial countries—Japan, the Federal Republic of Germany, and the United Kingdom. Productivity in the United States dropped almost 5 percent from 1973 to 1975, but increased 7 percent in 1976. Japan and the Federal Republic of Germany experienced productivity gains of 13 and 10 percent, respectively. With lower economic bases, other countries are expected to have larger relative gains. The continued slowdown in growth in productivity in the United States, coupled with accelerated growth abroad, however, may have serious long-term implications for the Nation's economic position.

Technology has repeatedly been shown to have a significant and positive effect on productivity. R&D today is one of the major sources of such technological change. To compare the results of all investigations of factors affecting productivity is impossible because all researchers have not focused on the same factors. Three studies utilized by the U.S. Department of Labor (1973) encompass similar factors and reflect current thought on this topic. Economists who did the studies concluded that three factors—improved technology, availability of more capital, and improved labor—have contributed substantially to the growth of productivity. Their estimates of the contribution of technology to growth range from 38 to 72 percent.

Our inquiry turned up only one report of forestry-related technology contributing to growth in productivity (Robinson 1975). The average rate of growth in value added per employee in the lumber and wood products industry was 5.2 percent per year from 1949 to 1970 (fig. 5). Labor and capital were responsible for 66 percent of the increase; increased technology, for 34 percent.

Increases in productivity due to the application of research findings are documented and commonly accepted (Fishel 1971). But attempts to measure the productivity increases are in the fledgling stage, mostly because of the lack of suitable data. Griliches (1979) noted the lack of suitable data and the inexactness of attempts to model the contribution of R&D to increases in productivity. Interestingly, he stated that in Federal research programs on defense, space, and health, the units of inputs are also used as output measures. He could have added agriculture, for the Forest Service too used scientist-years as both input and output.

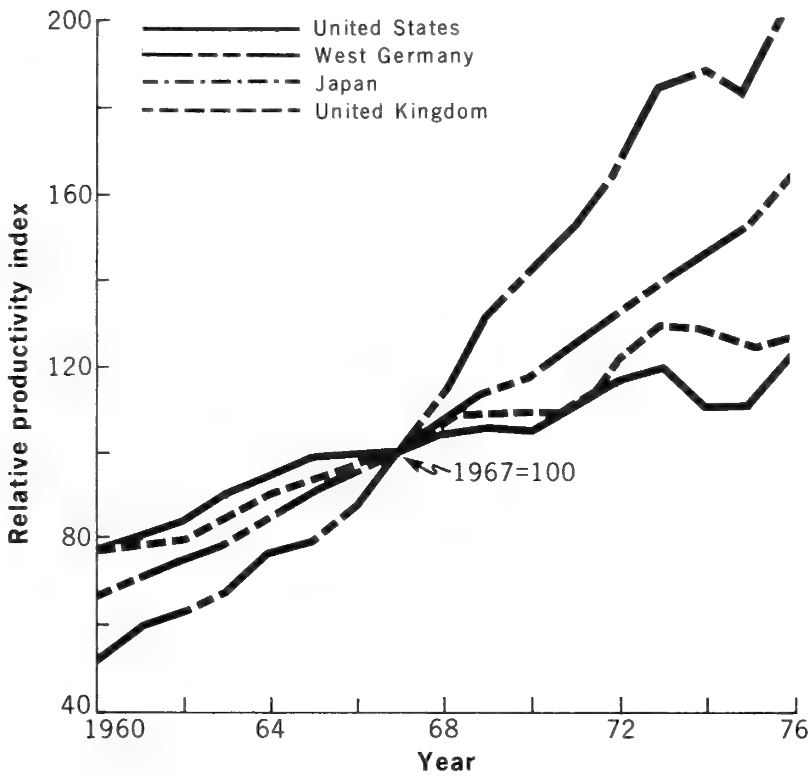
Internal Rates of Return from Research

Ruttan (1978) has collected information on rates of return from several areas of agricultural crop research. He points out that the use of "internal rates of return" seems to have eliminated the confusion and skepticism regarding validity of earlier estimates of "external rates of return." His compilation shows that internal rates of return for crops research are in the range of 30 to 40 percent. He argues strongly that the Nation is underinvesting in agricultural research.

In an *ex-ante* evaluation of pest management programs based on subjective future estimates, Araji (1978) derived future internal rates of return to additional public investment in pest management research and extension for 31 agricultural commodities, including "forests." Anticipated returns ranged from a high of 191 percent for soft, red winter wheat to a negative return for sweet corn. The internal rates of return for the major agricultural commodities ranged from 20 to 60 percent. Investment in pest management programs for forests showed internal rates of return of 60 percent without an accompanying extension program, and 87 percent with an extension program.

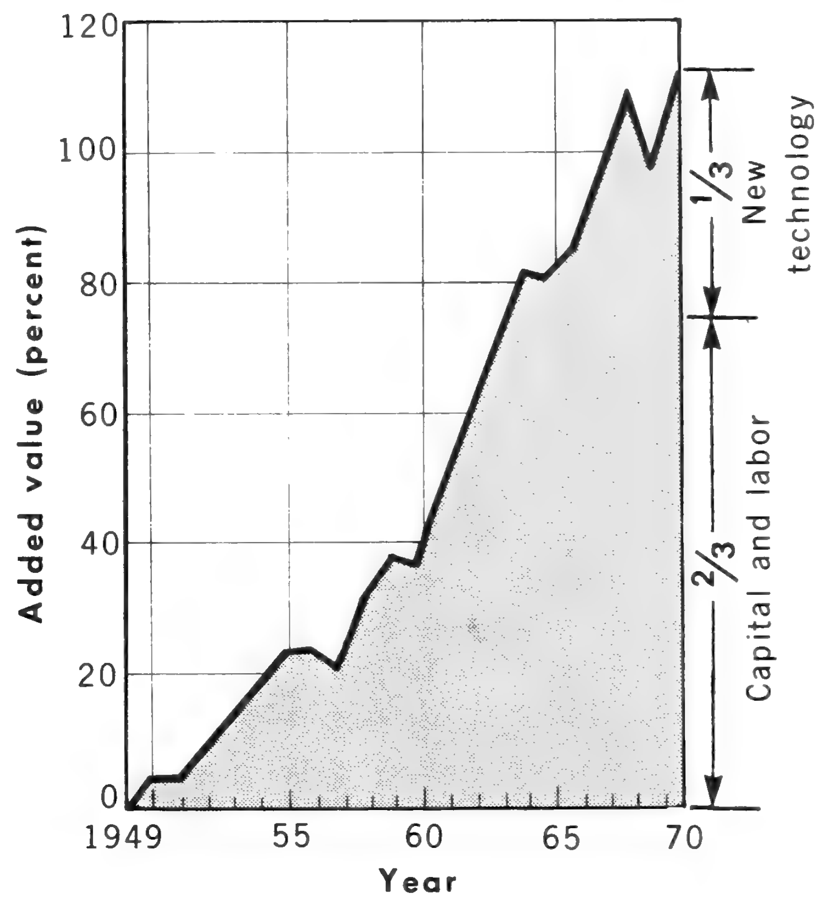
[6]Teams responsible for tasks contributing to this and the following section were led by R. Duane Lloyd (NE) and Dixie R. Smith (RM).

Figure 4



Productivity in manufacturing industries has risen higher in Japan and West Germany than in the United Kingdom and the United States.

Figure 5



New technology contributed one-third of the value added per employee in the lumber and wood products industry from 1949 to 1970.

Similar information for forestry research, although scant, shows internal rates of return similar to those for all other agricultural research—30 to 40 percent. Overall, the returns to the economy from selected areas of research that resulted in totally new outputs, such as southern pine plywood or composite boards, are undoubtedly adequate to support all of our extensive research program.

Altogether, increases in productivity or rates of return as gauges of the usefulness of research are in their infancy, even in sectors of the economy where production outputs are measured relatively well. Such is not the case in renewable natural resources, however, and so the work that Ruttan (1978) and Araji (1978) have collected is promising but not yet conclusive. Discussions with Araji and other knowledgeable economists led us to expect that internal rates of return from forestry research will parallel those from agricultural research.

Outputs and Benefits from Forest Service Research[7]

Forest Service Research has not done an adequate job of describing outputs and benefits resulting from its programs. Often, research has simply expressed its outputs as scientist-years (SY's) in the same way it expresses inputs to the research process. In fact, the various outputs from research contribute new knowledge and methodology—the foundations for advancement in technology and innovations. The estimated outputs from Forest Service research during three fiscal years were:

[7]The team responsible for tasks, contributing to this section was led by E. L. Shafer (WO), and George H. Moeller (NC) contributed significantly, as did H. Kenneth Cordell (SE).

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Outputs:	*1977*	*1978*	*1979*
Manuscripts published	1,988	1,780	1,954
Public patents awarded	13	12	4
Official position documents prepared	663	730	599
Training documents prepared	79	147	111
Computer models or programs placed in use	144	126	134
Slide talks produced	53	59	40
Films produced	11	6	6
Workshops, symposia, or training sessions hosted	609	479	691
Concultations documented	1,606	1,331	1,857
Management guidelines accepted	71	272	117
New trees or shrubs released	26	4	13
Prototypes developed and tested	58	45	74

These outputs constitute a variety of inputs to the technology transfer process. This knowledge and methodology, as it is picked up and put into use, results in innovations having societal benefits that reflect favorably on research. Each year, research units summarize their accomplishments and benefits that should accrue from their findings. Until this time, however, we have not looked backward over time to try to grasp the significance of an accumulation of outputs and benefits from Forest Service Research.

Knowing that our research outputs have been substantial and the benefits significant, we undertook a hindsight analysis of some innovations resulting from Forest Service Research. We portrayed outputs and benefits, analyzed costs and time required for their production, and judged the degree of success or adequacy of the innovations. The outcome of this preliminary effort indicates part of what has been produced in the recent past. It serves as a basis for suggesting what might happen in the future. And it argues strongly for improvement and broader use of hindsight analyses to portray the outputs and benefits of past forestry research and to improve decisions regarding future forestry research.

This limited hindsight evaluation of Forest Service Research focused on a few past accomplishments, and admittedly research continues on some of those selected. Time to delve comprehensively into the past was not available. Our purpose was not to expose all that had or had not been accomplished and the reasons therefor. In the short time available we had only time to meet two objectives.

1. The primary objective was to estimate some benefits and costs associated with selected past innovations across a wide range of research challenges and events.
2. A secondary objective was to describe important factors that contributed to successful innovations.

Procedure

Eighty-one innovations resulting from Forest Service Research were selected for hindsight analysis. Innovations are defined as beneficial advances in products, processes, or techniques realized as a result of research, development, and application. The innovations selected were not a random or representative sample from Forest Service Research. To illustrate the kinds and magnitudes of benefits that would be apparent in each group, innovations were selected to encompass all elements and activity groups of RPA:

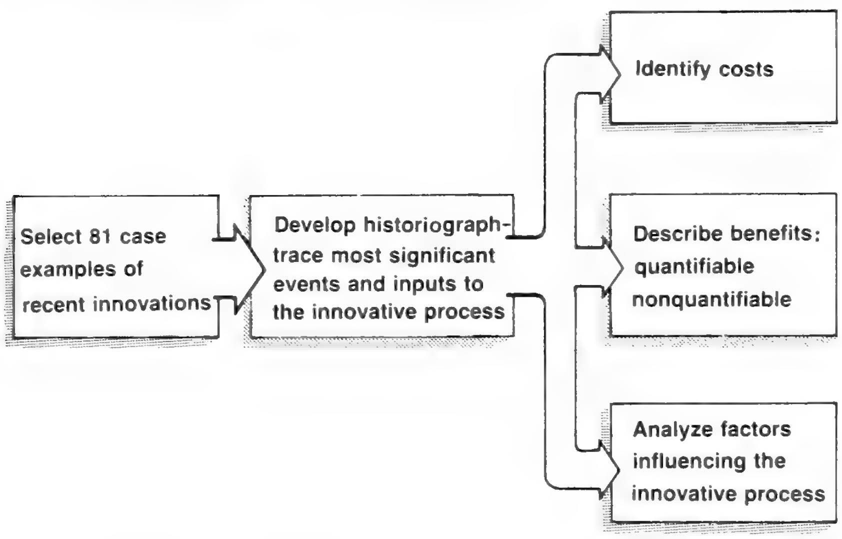
RPA Activity Group	*Regional/National Planning Area*	*Case Example*
Recreation	Recreation	Litter Control in Recreation Areas
Recreation (Wilderness)	Recreation	Wildnerness Distribution Model
Wildlife	Wildlife	Puerto Rican Parrot
Range	Range	Use of Shrubs for Reclamation
Timber Management	Biology: Genetics	Energy Plantations
Engineering	Harvesting	Tap Root-Whole Tree Harvester
Forest Products	Processing	Southern Pine Plywood
Water	Water	Peat Filter Beds for Campground Sewage
Pollution	Pollution	Revegetate Eastern Mined Lands
Environmental Values	Environmental Values	Sewage Sludge on Forests
Economics	Economics	Resources Allocation Model (RAM)
Resources Evaluation	Appraisal, alternative uses, and evaluation	Inventory Data Retrieval, Forest Resources Evaluation Program
Economics	Marketing	Housing Demand Model
Soils	Soils	Water Repellant Soils
Forest Insects and Diseases	Insects: Diseases	Fusiform Rust-Resistant Southern Pine
Fire and Atmospheric Sciences	Fire	Fire and Smoke Management

Knowledgeable national specialists in Forest Service Research nominated innovations recently produced by Forest Service Research. Innovations were selected on the basis of benefits or products resulting from the research; relevance to RPA activities; relative success of the innovation; and demonstration of a stream of events leading to the innovation.

Our process for hindsight analysis (fig. 6) was adapted directly from evaluations of biomedical research by the Battelle Memorial Institute (1973a, b), and as reported by Comroe and Dripps (1976). Scientists most closely involved with innovation were identified and contacted. Each scientist provided a historical narrative describing what happened, when and where it occurred, how it happened, and who was involved. A historiograph (fig. 7), was used to portray the innovative periods, events over time, and scientist-years required. This historiograph and the narrative were divided into four innovative periods:

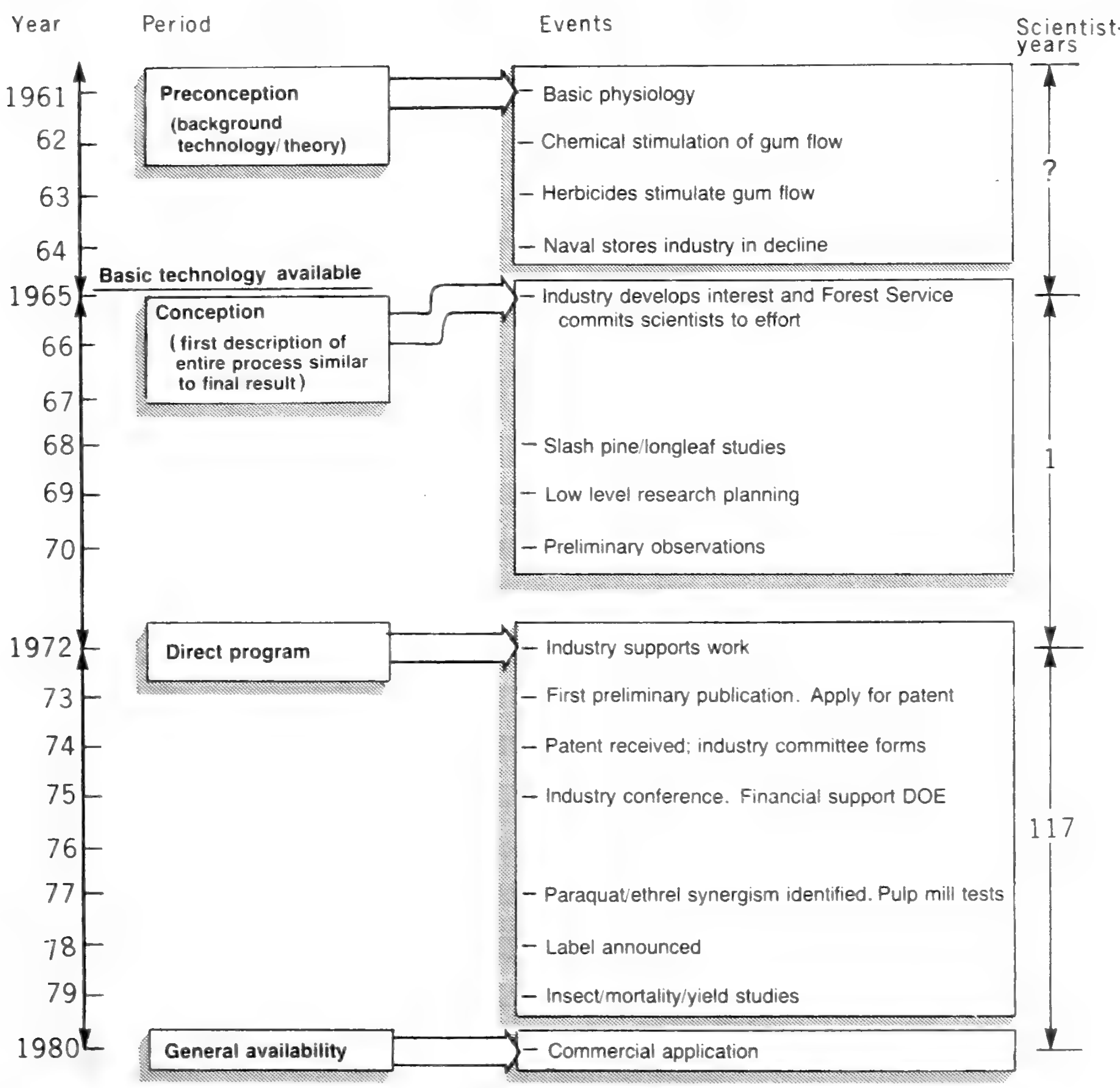
- Preconception: a period of research producing necessary knowledge, methodology, and theory culminating with

Figure 6



The hindsight analysis process identified costs, benefits, and influential factors in 81 recent innovations.

Figure 7



Totals:		Years	Scientist-years
	Conception	7	1
	Direct program	8	117
	Total	15	118

Hindsight analysis shows research on use of paraquat to stimulate resin production took 15 years and 118 scientist-years.

availability of all required technology and first conception of an innovation;

- Conception: a period of analysis of the problem culminating in the first description of the entire process needed to develop an innovation;
- Direct program: a period of development from conception to first realization of the innovation and its general availability; and
- Post innovation: a period of marketing, broad application, and diffusion of the innovation.

Information provided by the scientists was evaluated (fig. 8) by a five-member team. They worked closely together in order to assure comparability of evaluation of innovations. Each innovation was examined only as to kind and amount of benefits accrued, research costs incurred in terms of scientist-years, time required for research, and factors influencing the innovation process.

Benefits

Hindsight analysis shows that Forest Service Research has been extremely successful. Our society received more than 16 general categories of benefits from 81 case studies:

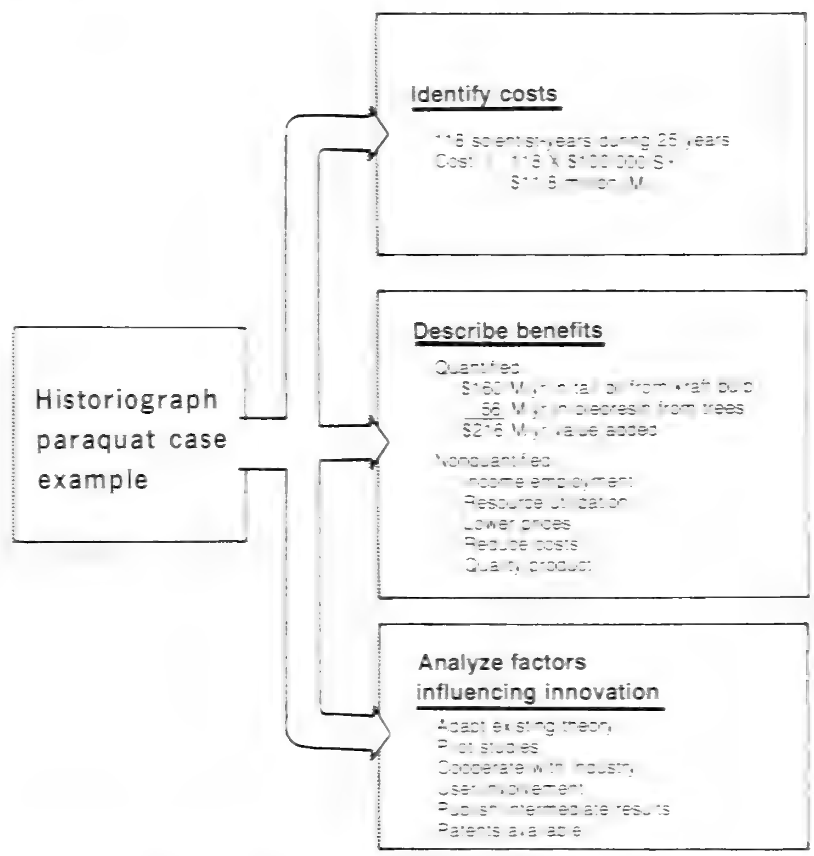
Benefits of 81 cases cited	*Number*	*Percent*
Generated income employment in forest industry or regional economy	43	53.1
Increased utilization of natural resources	42	51.8
Improved quality of physical biological environment	40	49.4
Lowered prices or costs to consumers	38	46.9
Reduced costs for managing resources	36	44.4
Improved methods for planning and evaluating alternative investments	34	42.0
Resulted in new and improved products	32	39.5
Improved visual environment and related amenities	30	37.0
Increased resource productivity	29	35.8
Reduced costs through improved processes	21	25.9
Improved scientific methods and theory	14	17.3
Improved social environment	12	14.8
Raised quality, lowered cost of housing	11	13.6
Enhanced health and safety	11	13.6
Improved cultural historical geological environment	9	11.1
Enhanced public involvement in decision making	8	9.9

At least half of the innovations resulted in benefits such as creation of income or employment in forest industries or the regional economy, increased utilization of natural resources, and improved quality of physical or biological environments. In 40 to 50 percent of the cases, new or improved products resulted, decisionmaking was improved, management costs were reduced, or lower prices and costs for commodities resulted. About one-third of the innovations resulted in improved visual environment or related amenities, or in management techniques to increase productivity of resources. Although other benefits were less often cited, they were significant in reducing costs, improving efficiency, and enhancing the public well-being.

Benefits were grouped into eight general categories and related to the innovations in each activity group (fig. 9). Predictably, benefits that generate income and cost savings through efficiency were most commonly associated with the hard science innovations in timber management, engineering, and forest products utilization. Surprisingly, however, recreation research had about 20 percent of its innovations recorded as generating income and cost savings, but the predominant benefits in recreation related to higher quality environment.

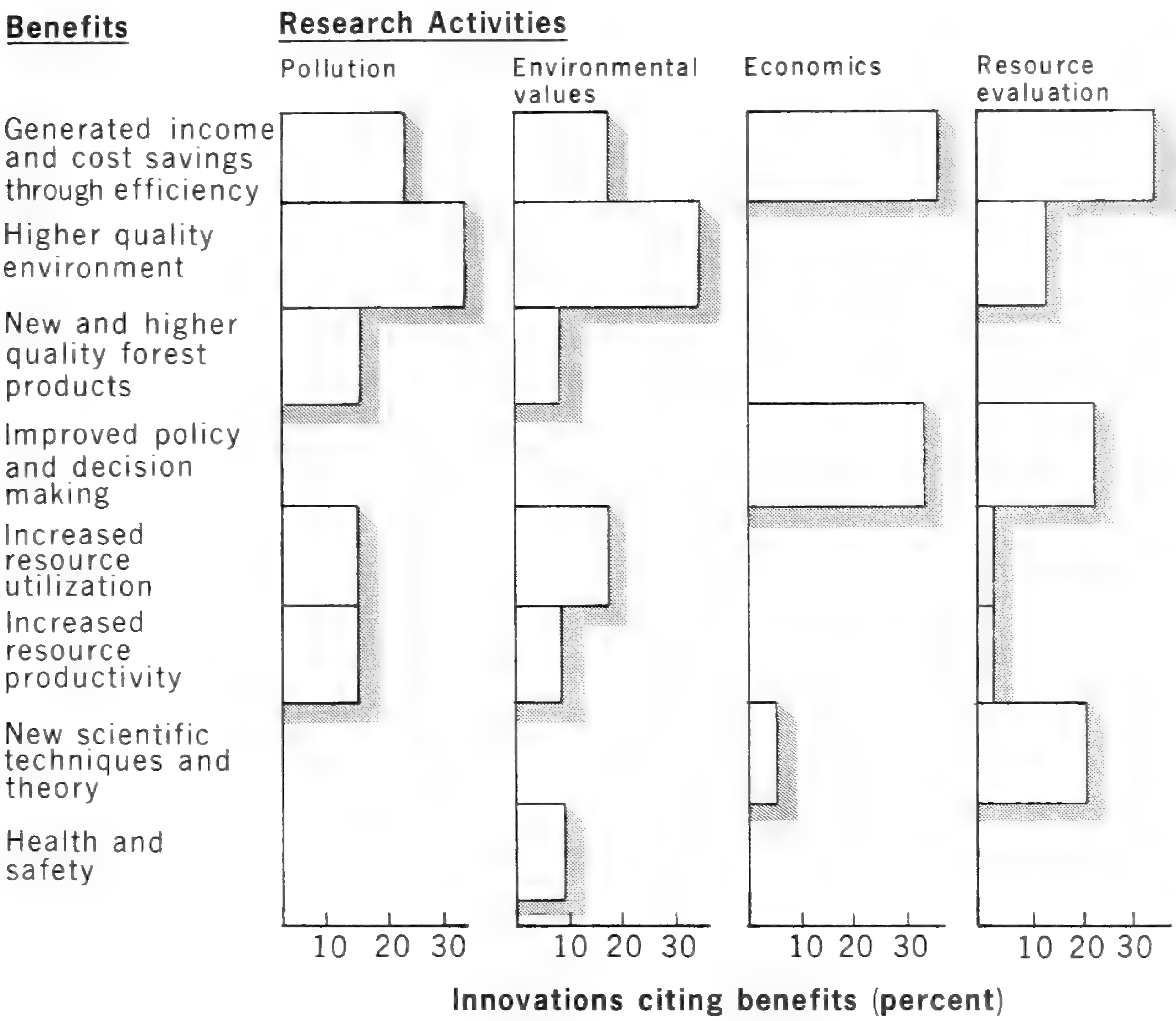
Although innovations were not selected to illustrate contributions to basic research, a benefit repeatedly attributed to the innovations was "new scientific technology, techniques, and theory." Thus, even applied or developmental research contributes to basic knowledge.

Figure 8



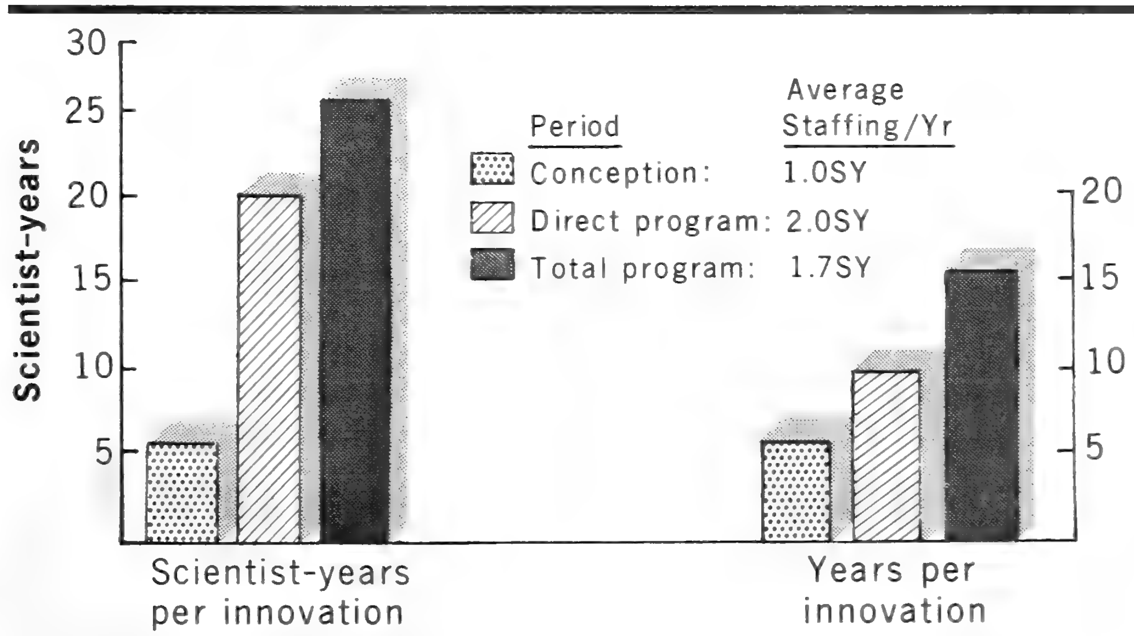
Hindsight analysis identified the costs, benefits, and factors influencing the innovative use of paraquat to stimulate resin production.

Figure 9



Frequency of benefits attributed to innovations from 16 research activities.

Figure 10



Average scientist-years, staffing, and time spent for 81 research innovations.

Innovative Period and Costs

Scientists estimated the calendar years that elapsed during the periods of conception and of direct program (fig. 10). The median time to produce an innovation, from conception to general availability, was 12.5 years, ranging from 3 to 48 years. The average time for the conception period was 5.4 years, and for the direct program period was 9.9 years. This combination resulted in an average innovation period of 15.3 years. Because the data were skewed, quartile ranges were used to summarize the distribution:

	Years	*Scientist-years*
Median	12.5	16.5
Quartiles		
Lower	3-8	2-8
Lower Middle	9-12	9-16
Upper Middle	13-20	17-24
Upper	21-48	25-148

Costs, in terms of scientist-years (SY's) devoted to the innovation, reflected a similar distribution (fig. 10). The average input during the conception period was 5.4 SY's; for the direct program period, 19.8 SY's; and for the entire innovative period, 25.2 SY's. Lacking data needed to estimate costs precisely, we simply assumed a scientist-year to cost $100,000. This was the actual cost per SY to the Forest Service in fiscal year 1977. Costs of these innovations averaged $2.52 million, but ranged from $200,000 to $14.8 million. Selected examples of innovations illustrate the great variability and range of scientist-years and time involved in the research process (table 8).

To produce more innovations in relatively shorter periods of time, several needs seem apparent: (a) substantial increases in research dollars; (b) sustained commitment in SY's; and (c) utilization of multidisciplinary and action-research approaches to converge on a problem and solve it quickly.

Because one quarter of all innovations, regardless of the commitment of dollars or scientists, require two or more decades for completion, we need to identify those problems and make the necessary assurances and long-term commitments for scientists and funding.

Benefits Versus Costs

Monetary benefits could be suggested for 22 of the 81 innovations. Benefits from the remaining innovations, although equally important, were qualitative in nature and not easily subject to analysis. Given our sketchy data, we were unable to analyze benefits or to determine internal rates of return to research investments. Benefits were estimated simply as the gross dollar value of an innovation during only the first year it was applied. Costs included only investments for research valued at $100,000 per SY for the entire innovation period. Costs incurred by users to utilize the innovation and realize benefits could not be estimated. Neither nonquantifiable benefits nor measures of future benefit streams were included. Even with these limitations benefits to society were substantial in relation to costs for this research (table 9).

Attention should focus not on individual comparisons of benefits to costs, but rather on the magnitude of quantifiable benefits. For the 22 innovations studied, the first-year benefits alone, $2.6 billion, exceed the cost of all prior Forest Service Research or would pay for the next 24 years of Forest Service Research at current costs. Considering that many other quantifiable benefits and innumerable nonquantifiable benefits have

Table 8—*Scientist-years (SY) and time to achieve selected innovations, by activity group and innovation period*

Activity group, and innovation	Innovation period: Conception SY	Yr	Direct program SY	Yr	Total SY	Yr
Recreation: litter control in wildland areas	3	2	14	7	17	9
Recreation: wilderness recreation distribution model	3	2	11	8	14	10
Wildlife: management of Puerto Rican parrot	1	2	16	12	17	14
Range: use of shrubs for range reclamation	5	6	16	30	21	36
Timber management: management of energy plantations	4	1	83	13	87	14
Engineering: southern pine tree puller	1	1	2	2	3	3
Forest product utilization: southern pine plywood	1	4	20	30	21	34
Water: peat filter beds for recreation areas	1	1	10	8	11	9
Pollution: plant selection for eastern mined lands	3	8	36	14	39	22
Environmental values: home energy saving with trees	2	9	10	10	12	19
Economics: Resources Allocation Model (RAM)	1	1	10	10	11	11
Resource evaluation: Forest Resources Evaluation Program (FREP)	7	6	11	4	18	10
Economics: housing demand	1	1	8	8	9	9
Soils: water repellent soils and fire management	6	6	15	12	21	18
Insects and disease: injection of systemic fungicide for Dutch Elm	2	2	15	8	17	10
Fire and atmospheric sciences: fire and smoke management	22	10	36	4	58	14
Average for all innovations, all activity groups	5.4	5.4	19.8	9.9	25.2	15.3
Scientist-years per year	1.0		2.0		1.7	

resulted from Forest Service Research, a logical conclusion is that investments in such research yield a high rate of return.

Factors Affecting Innovations

The innovative process is comprised of myriad events, some of which happen sequentially and some concurrently at different places. Following similar procedures as those used by Globe and others (1973), a content analysis was done on documented events for all innovations. From all events, 22 factors were identified as major determinants of the successful innovative process (table 10). Specifically, for those innovations studied:

- About 37 to 40 percent of the time: utilization of existing technology, techniques, or equipment, or process or pilot testing was involved.
- About 20 to 30 percent of the time: cooperation with private industry, theory development, personal contacts with potential users, or computer analysis capabilities played important roles.
- About 10 to 18 percent of the time: cooperation with State and local governments, National Forest System, universities, and other Federal agencies, development of special techniques, publication of intermediate results, demonstration of the innovation, legislation or policy change, or development of special equipment appeared.
- About 5 to 7 percent of the time: cooperation with public and quasi-public groups, changes in environmental standards or laws that influence or initiate the process, significant financial support outside the Forest Service, multifunctional approach, patents, serendipity, or international cooperation was required.

To gain a better understanding of how important the 22 factors are during different phases of the innovative process, we grouped them according to the three innovative periods: conception; direct program; and post-innovation (table 11). This provides a better way to determine how important general factors are within periods, and to compare their relative importance through the entire process.

During the conception period, successful research depends most on the degree to which relevant theory has been developed to support the research. Availability and accessibility of computer technology is next most important. Finally, clear legislative mandate, or policy pronouncements, or both prompting the need for the research are important during conception.

As might be expected, factors related to the research process itself—availablility of techniques and equipment, ability to pilot test procedures, research support, etc., are most important during the direct program period. But, of almost equal importance, is the amount of cooperation with other public and

Table 9—*Estimated time for innovations to repay costs of research, by costs and estimated benefits*

Time needed to repay costs, and innovation	Total costs[1]	Estimated first-year benefits
	Scientist-Years	*Dollars*
One month or less:		
Differential campsite pricing	5	55 million in revenues
Paraquat for induction of lightwood	118	160 million in tall oils produced from kraft pulpwood. 56 million in increased production of oleoresins.
Bark chip separation/segregation	19	240 million in harvested fiber
Mechanized thinning of northern hardwoods	3	100 million in harvested fiber
Mobile chipper for residue recovery	3	75 million in residue fiber
Single-line long-reach yarder	2	10 million saving in logging road costs
Residue harvesting program	52	85 million in logging residue. 50 million dead timber harvested.
Best opening face	10	32.4 million value added in lumber
Short log milling	7	7.5 million added revenue to forest owners. 375 million savings to pallet industry.
Making wide boards from small logs	14	60 million in value added to lumber
Home energy saving using trees	12	738 million in oil saved. 477 million saved in space-conditioning.
Multiresource inventory system	2	2.5 million savings in costs
Fusiform rust resistant southern pines	22	27 million savings in timber value
One month to 1 year:		
Aerial direct seeding of southern pine	10	1.8 million savings in planting. 1.9 million value added to growth
Revegetation of arid lands in the Southwest	6	6 million savings in revegetation costs
Inventory data retrieval	2	250 thousand savings in data retrieval costs
Bark residues	12	2.1 million value of marketed product
Biocontrol of larch casebearer	19	10 million savings in timber value
One to 5 years:		
Wilderness sanitation	9	700 thousand savings in waste disposal costs
Peat filter beds for treatment of campground	11	450 thousand in sewage treatment costs
Sewage sludge disposal on forests	47	500 thousand savings in sewage disposal costs. 500 thousand value of increased growth.
Improved control of pales weevil	12	210 thousand added to timber value

[1] Total cost assumed as $100,000 per scientist-year (SY) to develop the innovation.

Table 10—*Rank of factors influencing the innovative process, by frequency of mention*

Rank	Factor	Innovations mentioning this factor	Frequency (percent)
1	Adapt existing techniques, technology, or equipment	32	[1]39.5
2	Demonstrate feasibility by process testing or pilot studies	30	37.0
3	Cooperate with private industry	24	29.6
4	Develop adequate theory before applied research could proceed	23	28.4
5	Personal discussions and contacts with potential users during research	17	21.0
6	Access to computer hardware and software	17	21.0
7	Cooperate with State and local government	15	18.5
8	Cooperate with National Forest System	15	18.5
9	Cooperate with universities	14	17.3
10	Develop special techniques	11	13.6
11	Cooperate with other Federal agencies	10	12.3
12	Publish intermediate results	10	12.3
13	Demonstrate technology, equipment, or process	10	12.3
14	Change in legislation or policy prompted need for the research	9	11.1
15	Develop special equipment	9	11.1
16	Cooperate with public and quasi-public groups	6	7.4
17	Changes in environmental standards or laws are required before research is applied	5	6.2
18	Significant financial support from outside the Forest Service	5	6.2
19	Multifunctional approaches required	4	4.9
20	Required patents	4	4.9
21	Serendipity	4	4.9
22	Cooperate internationally	4	4.9
	Total	278	—

[1] $(32/81) \times 100 = 39.5$ percent.

Table 11—*Index of probable importance of factors influencing the innovative process during each period*

Innovative period	General factors[1,2]	Index of probable importance	
		Within period	Across all periods
Conception	Legislation or policy (14)	18.2	3.2
	Computer technology available (6)	34.7	6.1
	Adequacy of theory development (4)	47.1	8.3
	Subtotal	100.0	17.6
Direct program	Financial support (18)	2.4	1.8
	Technology transfer (5, 12)	12.8	9.7
	Cooperation (3, 7, 8, 9, 11, 16, 22)	41.8	31.6
	Research process (1, 2, 10, 15, 19, 21)	43.0	32.5
	Subtotal	100.0	75.6
Post-innovation	Technology transfer (13, 17, 20)	100.0	6.8
	Grand total	300.0	82.4

[1] General factors that influence the innovative process were developed from the list of 22 specific factors contained in *table 10*, and classified by innovative period.

[2] Numbers in parentheses identify specific factors in *table 10* that are grouped to form the general factor.

private research organizations and with users of research. Another important factor is the degree to which technology transfer activities are incorporated into the research process. Specific technology transfer activities include involvement of users in the research, publication, and discussion of intermediate research results, and general coordination with user groups. Although financial support was not ranked as highly important during the direct program, it must be kept in mind that the innovations studied were all successful through first realization. Consequently, funding must have been sufficient. Certainty of financial support throughout the direct program appears to be a necessity.

Technology transfer activities—demonstration of results, summary publications, workshops, involvement of user groups, etc.,—play a dominant role in the post-innovative period. Also important is the need to obtain necessary patents and changes in existing laws, procedures, policies, regulations, etc., so that the innovation can be widely applied.

In all, seven independent factors significantly influenced the innovative process. As would be expected, factors related to the research process itself are highest in overall influence, but nearly as important are cooperative relationships with other research organizations and with research users. Technology transfer activities, both during the conduct of the research and during the post-innovation period, were next most important. Three other factors—available computer technology, adequacy of theory, and legislation or policy—are important mainly during the conception period. The last factor identified was adequacy of financial support through the direct program period.

Response to National Policies

Any decision about a single Federal research program should be made in the light of overall national policy on science and technology. Unfortunately, a succinct statement of national policy does not exist. Rather, the amorphous shape of national policy emerges from countless pronouncements of national leaders and from actions of the Congress. Sometimes these are explicit and directly applicable to research. At other times, as in the case of constraints on Federal employment, they are implicit. After gleaning messages, speeches, reports, and hearings, we present a sampler, in context, suggesting the policies to which decisions about Forest Service Research should conform.

Status of Science and Technology[8]

The status of science and technology is obscure because no firm national policy has been enunciated against which progress can be gauged as a criterion for decision. Pizer (1974) succinctly assessed the situation this way: "Those who pursue science all agree that the primary flaw in the way the nation handles science is the failure to devise a rational, consistent policy." Philip Handler (1979), president of the National Academy of Sciences, concurred: "This country has never had a science policy. We never looked at the subject in its entirety and formulated an intelligent, overall approach. What we have had is bits and pieces of ad hoc policies to deal with bits and pieces of science; often they were wasteful if not downright counterproductive."

Along a similar vein, Pizer (1974) urged that "the Federal Government must for the first time in history frame an overall policy that eliminates crash-basis science, erratic funding, and submission to faddish enthusiasms, and that substitutes consistency, continuity, balance, between research and application, and long-range planning relating science/technology to national needs and goals."

Richard C. Atkinson, director of the National Science Foundation, reflecting on funding levels of science during the era beginning before World War II (Leeper 1977b) said: "So we've had a period of really dramatic oscillations in the support of science. That has not been healthy for science, and it's not been healthy for the long-term interests of this country. So I hope that . . . we can really establish a much sounder base for the support of research."

President Carter's (1979c) recent science and technology message to the Congress, already quoted earlier, included the following statement:

> . . . if we are to make the best use of our scientific and technological progress, we must maintain continuity and consistency in our support and policies. This Nation's scientific capability is the greatest in the world, but it will not remain so in an environment of uncertainty and changing priorities and policies. We must recognize that it takes many years to train new scientists and to complete some research projects. Technology development projects and many research missions, such as our space probes, require sustained work over a decade. If research and development activities are started and stopped abruptly, the chance of their success is diminished and the probability of benefits to the Nation decreased. The Congress and the Administration must join in recognizing the long-term nature of many research and development activities. Together we must provide the necessary assurances and commitments. The policies of my Administration, as articulated in this message, are intended to serve the purpose.

President Carter's (1979a) budget message, delivered 2 months earlier, however, tempered the above declaration somewhat—at least for FY 1980—with these words:

> . . . I believe that the Federal Government must lead the way in investing in the Nation's future. This budget, therefore, continues my policy of providing real growth in Federal support of basic research. This support amounts to a relatively small part of the total budget—$4.6 billion in 1980—but it is vital to the future of our Nation. The knowledge created through basic research holds the potential for breakthroughs to the solution of problems we face or may face in such critical areas as agriculture, health, environment, energy, defense, and the overall productivity of our economy.
>
> . . . . .
>
> I have chosen restraint in Government spending because inflation must be controlled. I have tried to be equitable in ordering priorities. Yet I have continued to support those programs that represent our most pressing needs. To do so I have terminated, reduced, and deferred other programs.

Forestry science, though beset by the same lack of guiding policy as science in general, differs in one respect. Section 8 of the RPA requires that the assessment and program transmittal to the Congress be accompanied by a Presidential Statement of Policy, which serves as the basis for Forest Service budget requests. The Statement of Policy is subject to Congressional review for 90 days during which either House may disapprove. The Congress may revise the statement or accept it without change. Since neither the 94th Congress nor the 95th Congress took any action on the Statement transmitted in 1976, it remains in effect as received and is to be used for all budget requests until the updating of the assessment and program. The Act further requires that if the President departs from the Statement of Policy in making the budget request, the reasons therefor must be made public (House of Representatives 1977).

The President's executive budget for FY 1980 proposed a reduction of $272 million from the amount appropriated for the Forest Service in FY 1979, including a decrease of $7.24 million for research. The funds proposed for most Forest Service activities were below the levels recommended in the program submitted in 1976 pursuant to RPA of 1974. The budget, therefore, stated that despite departures from program recommendations submitted in 1976 (Office of Management and Budget 1979, p. 152):

> The 1980 budget is . . . consistent with the statement of policy transmitted at that time, which noted that additional evaluation of these recommendations

[8]The individual responsible for the task contributing to this and the following section was Vinson L. Duvall (SO).

would be necessary to support the program, and that the recommendations should be considered in the context of total Federal priorities and the overall size of the budget. The administration is conducting further planning and evaluation as the basis for revised recommendations required in calendar year 1980 under the 1974 Act.

Need for Science and Technology

Decisions about research programs, reflecting how much and why now, should be made in the light of justified needs for investigation. Needs as expressed by the scientific community must be compared with and tempered by expressions of need from users of new technology. Modern scientific literature is replete with statements about the need for continuing advancement in science. Since 1972, for instance, more than 30 reports have been issued on studies that were concerned with the adequacy of agricultural research. And virtually all of them urged increased funding. Such findings not only expressed views of the scientific community, but they often either originated with or were endorsed by political leaders, users of agricultural technology, and resource conservation advocates.

One such expression is from Philip Handler (1979). In testimony before the Subcommittee on Science, Research, and Technology of the U.S. House of Representatives, Committee on Science and Technology, he expressed concern over adequacy of research that related closely to forestry:

> As we turn to the subject of science in the next few years, it should be no surprise that our principal harvest has been to learn what questions to ask next. These questions will be more difficult to address than those we tried yesterday. They will deal with phenomena more remote from our senses, requiring more elaborate and sophisticated instruments and facilities. Science tomorrow will be intrinsically more expensive than was science yesterday.
>
> . . . . .
>
> Concern for the quality of the environment will continue. The basic processes involved—photosynthesis, denitrification, mineralization, gas absorption, volatilization, and so on—are scientifically understood at the primary level but not in the gross dimensions of real concern. . . . Some of the major subjects demanding examination are the following:
>
> - Cleansing of the atmosphere by forests and other natural and managed vegetation.
> - Impoverishment of soils caused by acid precipitation.
> - Influence of precipitation on the quality of lakes and streams, and the alterations in aquatic vegetation and fauna caused by deposition of acid substances.
> - Increases in the abundance of heavy metals in food crops and natural food chains as a result of direct deposition from the atmosphere and mobilization in soils due to acid precipitation.
> - Fate of volatile pesticides and other chemicals used in agriculture and forestry, and their effects on humans and the environment.
> - Substances and processes involved in atmosphere-biosphere exchange.

T.W. Edminster, administrator of the Agricultural Research Service, U.S. Department of Agriculture, in testimony at special oversight hearings before subcommittees of the Committee on Science and Technology, U.S. House of Representatives, expressed concern ". . . about the likelihood that we cannot sustain the rate of flow of new technology we have enjoyed in recent years, despite our great confidence in the agricultural research system in the United States." He based his concern on the following conditions (House of Representatives 1975):

- General slippage in research capacity during the past 10 years due to inflationary costs;
- Higher constant dollar costs of research, which is increasingly complex in its approach;
- New and greater responsibilities to maintain and improve the environment;
- Increasingly regressive pressures placed on high-yielding plants and animals by the environment, insect pests, and diseases;
- New technology demands caused by high energy prices, the use of marginal lands, consumer demands, and the inability to use certain existing technology;
- Persistent and formidable yield barriers, and, lastly, the erosion of our technology.

Brock Evans (1978), Director, Washington Office, Sierra Club and Federation of Western Outdoor Clubs, remarked on research needs before the National Working Conference on Research for Forests and Associated Rangelands:

> One of the things I think we are most agreed on is the need for more research. . . . Our member groups have shared many struggles over the years . . . struggles for better forest and range management, struggles to assure more consideration of fish and wildlife, struggles to protect certain parts of our public lands. In each one of these issues, the one great crying need was for facts, the kind of hard, uncontrovertible data from unquestionably reliable sources that everybody could rely on.

The first report of the National Agricultural Research and Extension Users Advisory Board (1979) contained the following statement:

> The Board believes that agricultural R&D expenditures by the U.S. Government is a high priority investment of public funds. Generally speaking, such investments have yielded benefits to both producers in the form of lower costs and to consumers in the form of lower prices. However, such benefits cannot continue to be reaped without sustained investments in agricultural R&D. We believe that the level of such investments has been too low for some time and a real increase in funding is required. We do not expect that a dynamic and productive agriculture which meets the many needs of our complex society will be possible without this basic commitment to R&D funding.

Commenting on the proposed reductions for agricultural research in the Executive Budget for 1980, the Joint Council Budget Committee (JCBC) (1979) incorporated the following views into its report:

> The JCBC cannot comment on the value of research and development outside the USDA but it does believe that the social payoff of research, extension and education in the Food and Agricultural Sciences has not been appropriately recognized. Careful studies have estimated that the social rate of (annual) return to public investment in agricultural research is between 30 to 40 percent. There appear to be very few opportunities for public investment that are as attractive. In spite of the increased visibility for agriculture during the past five

years, the discussions regarding the value of U.S. agriculture and its contributions to the U.S. economy and to world peace, the explicit language of Title XIV (of PL 95-113), and the recommendations of numerous studies conducted by several prestigious scientific groups, all suggesting that agricultural research and development should be increased, the Executive FY 80 budget is clearly not responsive to these established needs and concerns.

The JCBC added that "With these impending budget constraints, it is doubtful if SEA, ESCS, and FS will be able to react effectively to indicated needs and legislative mandates."

W. David Hooper (1976), president of the International Development Research Centre of Canada, took a different approach in appraising the importance of returns from investments in agricultural research: "The relevant question for mankind, however, may not be one about investment return. It may rather be: What is the longrun cost of not initiating now a program of investing in man's future food supply? Water-resource development has a long gestation time before it yields benefits."

The same analogy is applicable, of course, to the development of forest and range resources for production of fiber, food, and other resources. Not only have numerous studies treated the need for agricultural research, but a substantial number have recommended how public funds should be allocated to the various institutions engaged in such research. One of these, the "Pound Report," compiled by Dean Pound of the College of Agriculture, University of Wisconsin, for the National Research Council (1972), recommended:

That the USDA seek a greatly increased level of appropriation for competitive grants program, which should include support of basic research in the sciences that underpin the USDA mission. These appropriations should be . . . available to scientists in the USDA, in land-grant and nonland-grant public universities or colleges and in private universities or colleges, and other research agencies. The committee recommends further that this program be administered in such a way that research proposals are subjected to evaluation by peer panels of selected scientists drawn from those eligible for support, and that the administration should not be the same as that making allocation for USDA in-house research.

President Carter (1979b), in his science and technology message to the Congress, urged strong Congressional support for the competitive grant program to help meet further agricultural needs.

The Joint Council Budget Committee (1979) recognized the importance of a "program of competitive grants for all colleges and universities. . . ." However, its report emphasized the need for in-house research: "It is imperative that strong and viable food and agricultural research programs in the USDA be continued. These 'in-house' research programs must have a critical mass to be able to deal effectively with national and mission-oriented problems and the ability to respond to critical emergency situations as they arise."

Assistant Secretary of Agriculture M. Rupert Cutler (1978), addressing the National Working Conference on Research for Forest and Associated Rangelands, stressed the value of competitive grants and in-house research:

I plan to give strong support to adequate funding of competitive grants for forestry research as soon as such a program is authorized by the Congress. . . .

. . . . .

The importance of continued base funding for major forestry research-performing organizationsn such as forestry schools, agricultural experiment stations and the Forest Service cannot be overemphasized. Base funding for research under the McSweeney-McNary and McIntire-Stennis Acts, and from State sources, is essential because it's impossible to maintain a strong, balanced staff of scientists on competitive grants, or 'soft money,' alone.

The National Agricultural Research and Extension Users Advisory Board (1979) announced that it:

. . . endorses the concept of competitive grants as a desirable method of supplementing the research of USDA. The goal of stimulating innovative research and involving nongovernmental scientists is worthy.

. . . . .

However, the Board feels that the competitive grants program must not be funded at the expense of either in-house USDA research or the established cooperative research apparatus. This appears to have happened either directly or indirectly, in the executive budget proposed for FY 1980.

Philip Handler stressed the need for mission-oriented agencies to conduct research (Leeper 1977a): "Since every major department of the government has a technological component, it seems imperative that each one manage enough science to make sure that its technology program is a good one. . .If you take the research out of all those (departments of government) and put it in some funny package called 'science and technology,' it will all go sterile . . ."

Constraints on Federal Employment[9]

One clearly stated national policy to which research must respond is that Federal employment will be constrained; thus, decisions about growth in research programs automatically raise questions about more Federal hiring. Each recent President of the United States has set ceilings on employment in order to hold down or reduce the Federal work force. In essence, the current policy is to do more research with relatively fewer Federal employees. Such constraints and policy can be expected to persist, perhaps to be accentuated, in the decade ahead. How has Forest Service Research fared under such a policy in the past? Could Forest Service Research programs expand appreciably in the future without more employees?

During the 1970's, Forest Service Research grew in funding, but shrank in number of employees. Consequently, the propor-

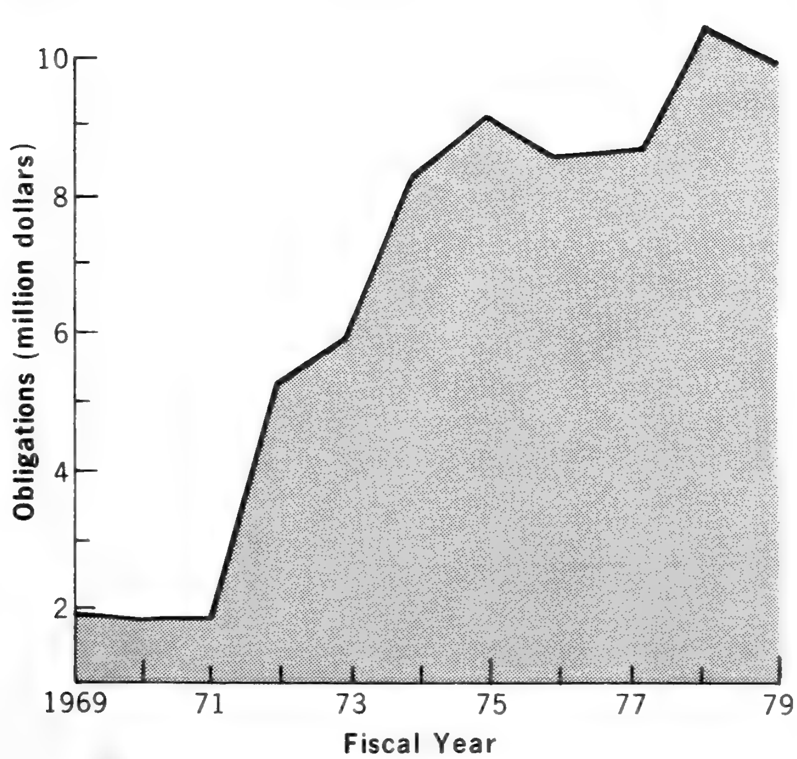
[9]The individual responsible for the task contributing to this section was Paul C. Guilkey (PSW).

tion of appropriated funds obligated directly for extramural research climbed steadily from about 2 percent of appropriations in FY 1969, to 10 percent in FY 1979 (fig. 11).

Direct obligations for extramural research in FY 1978 were \$10.4 million and in FY 1979 were \$9.9 million. Most of these obligations (67 percent) were for cooperative aid research in which Forest Service scientists had a direct, substantial involvement (fig. 12). One recent study found that 4 scientist-years bought through cooperative aid fully obligated one scientist-year within the Forest Service. About 32 percent of the obligations were for grants, which had little effect on the time of Forest Service scientists. Only about 1 percent of obligations were for contracts.

A recent study indicated that the appropriation level costs, being greater than direct obligations, for extramural research totaled \$20.7 million in FY 1979. The share of appropriations to the performer, \$10.97 million, amounted to 53 percent. A nearly equal share (47 percent) was obligated intramurally for research management and support services (25 percent) and for scientific input (22 percent). Because cooperative research predominated, these proportions might not hold for greatly expanded extramural research programs.

Figure 11

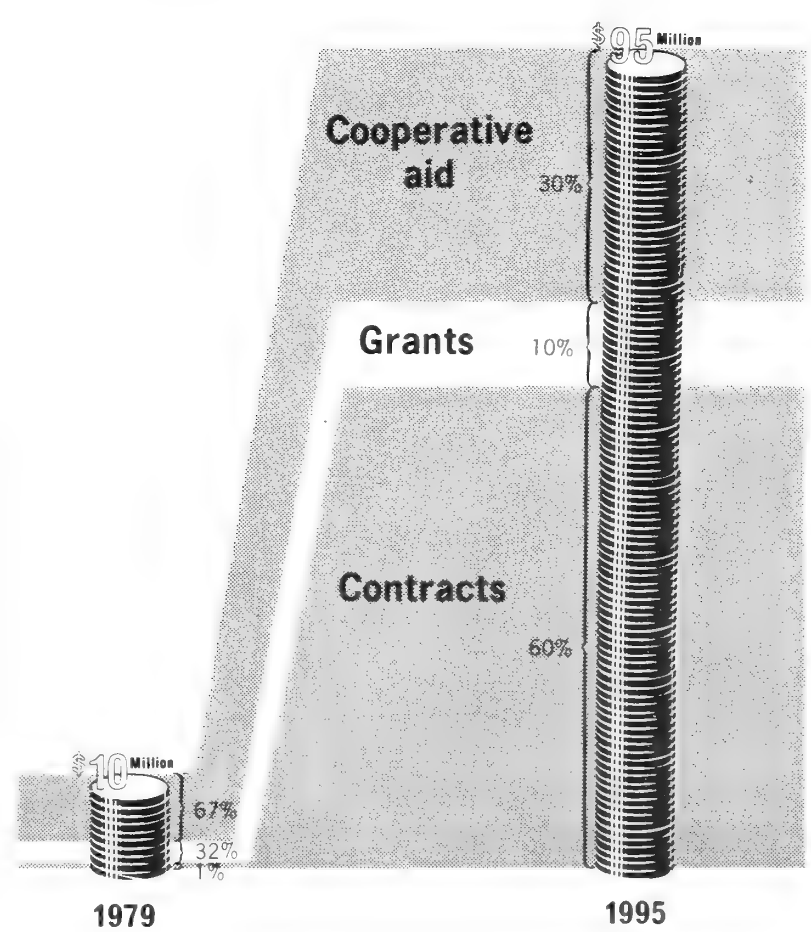


Forest Service Research funds obligated directly for extramural research rose from \$1.9 million to more than \$10.4 million from 1969 to 1979.

All indications are that the economic efficiency of extramural research may be equal to, but probably is less than, that of intramural research. Real benefits are to be gained from extramural research as well as from intramural research. And each has its limitations as well.

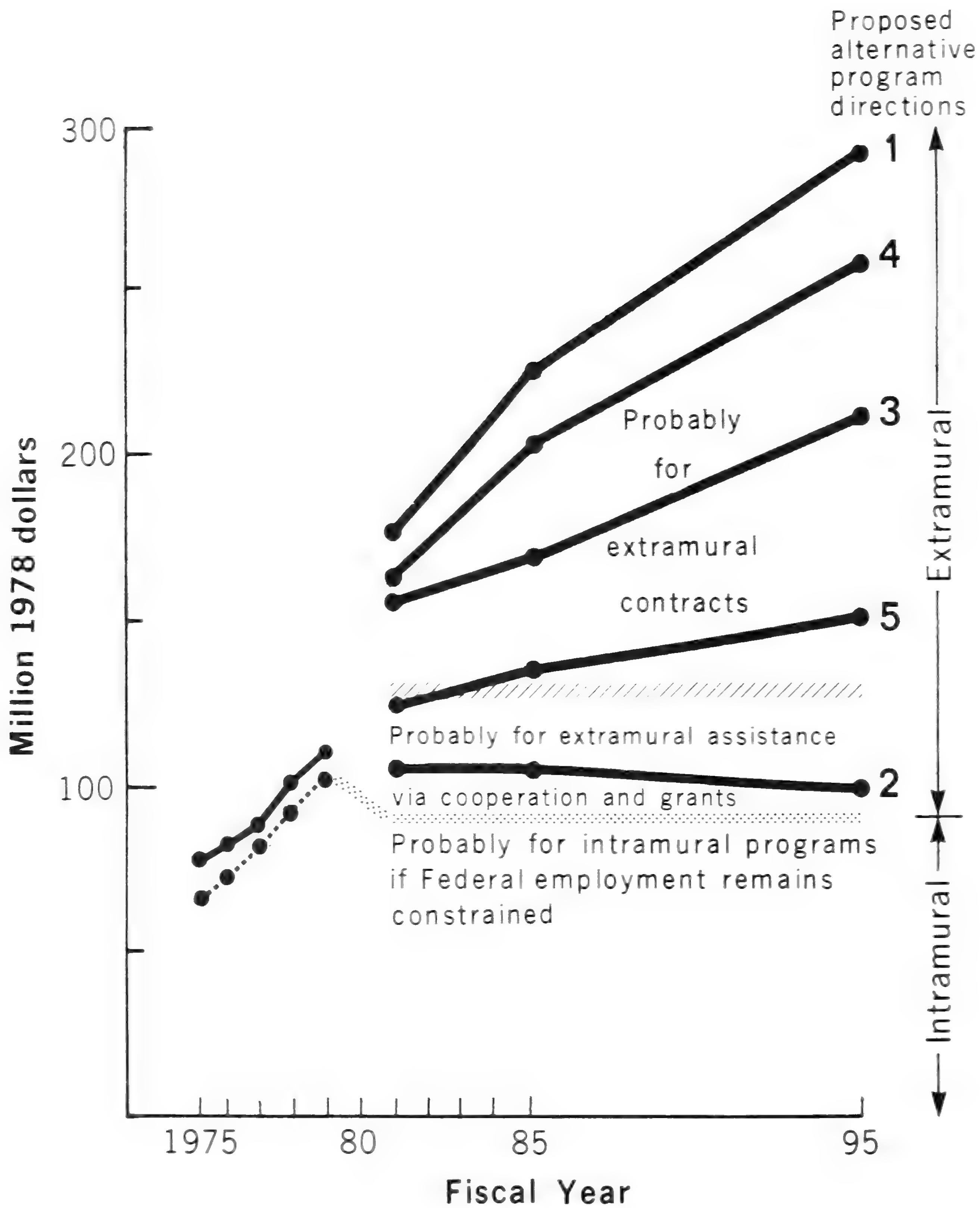
If extramural research were to be expanded considerably, would there be enough scientific talent available to utilize funds effectively? Our best estimate is that moderate expansion of research programs, to APD mid-level 3, would increase demand for extramural scientists fivefold (fig. 13). At the highest APD level 1, demand would increase sixfold. A five or sixfold increase in demand for scientists probably can or would be met quickly, except for a few categories recognized as in short supply, i.e., economists and mensurationists. Conversations with educators and others in the private sector indicate that a sizable supply of scientists with advanced academic degrees currently is underemployed and would be available for an expanded program of forestry research.

Figure 12



Expanded funding for Forest Service Research would change the mix of extramural research.

Figure 13



Increases and changes in the management of extramural research are projected at each of the five alternative program levels.

The extramural research program has emphasized cooperative aid, but has shifted lately toward more for grants. Grants increased from 23 to 32 percent of extramural obligations between FY's 1978 and 1979. Cooperative aid utilizes and consumes the capacity of Forest Service scientists directly in research. Our studies lead us to estimate that Forest Service obligations for extramural research could increase about $20 million above current levels, before capacities of Forest Service scientists to participate in cooperative research would be fully utilized. Increases in annual funding for research above the level of about $130 million (in 1978 constant dollars) would go not into cooperative aid, but rather into grants, contracts, essentially extramural R&D programs, and "captive laboratories."

We asked other agencies about the numbers of employees required to manage extensive extramural research programs. They responded that about four to seven intramural positions are required to manage each $1 million of extramural research. (Incidentally, at the current annual cost to Forest Service Research of a permanent full-time employee, $41,400, intramural costs would add from 16 to 28 percent to direct costs.) Therefore, we estimated the effects of funding research at APD mid-level 3, with current constraints on employment. Forest Service Research would have to redirect about 380 (1 in 7) of the current 2,600 permanent full-time positions to manage extramural research estimated to cost directly about $95 million by 1995 (fig. 12).

In the near future, each $10 million increase in appropriations, beyond the level of about $130 million, would require redirecting about 55 to 60 positions, or about five to six at each Experiment Station. If normal rates of attrition and turnover are considered, the Stations could accommodate such redirection easily. If funding for research suddenly jumped to $180 million, redirection of 280 to 300 positions would significantly affect the current work force at Stations.

Of the positions to be redirected about 45 percent are now occupied by scientists. This is the proportion of scientists now working in Forest Service research work units. The others would be supporting personnel in research work units who would be released so more professionals could be hired to manage contracts, grants, and R&D programs.

We asked those who might benefit from such an expanded extramural research program, and this was their response: $40 to $60 million could be obligated in the first 1 to 2 years, with subsequent expansion possible in 3 to 5 years. Cooperative aid research could be boosted easily to a total of $25 to $30 million. Contracts and R&D programs could be obligated for another $15 to $30 million. Basic research could immediately absorb $5 million. Immediate needs of international forestry range from $2 million to $7 million.

Ceilings on Federal employment do not seem to limit decisions about alternative levels of funding for Forest Service Research in the future. Major budgetary increases requiring expansion of extramural programs would be anticipated for a year or two before they were received, providing sufficient time to mobilize, redirect, and arrange timely obligations for extramural research.

Relation to Historical Trends

Research does not prosper in a dipsy doodle world. Given a conception period averaging 5.4 years, a direct program period averaging 9.9 years, and average gestation for an innovation of 15 years, Forest Service Research requires "continuity and consistency in our support and policies." That phrase, from President Carter's (1979c) science and technology message, certainly is apropos to decisions about forestry research. His other remarks, to the Congress, attest, at the highest level, to decisions providing for long-term "assurances and commitments" toward research.

Research in the USDA is very much a team effort with divided authorities and responsibilities. Participants on the team fare better in some years and worse in others in the competition for appropriations. Only by stepping back in time, can one see how well different participants have done in this competition. Has Forest Service Research won, lost, or stayed even with other research agencies in the USDA?

In this competition for funds, Forest Service Research seeks foremost to solve practical problems. These problems emerge dynamically from action programs of Federal and State agencies, industries, and other private landowners. Changes in the tempo or direction of such action programs usually demand concomitant changes in research. A historical perspective helps to understand how research has or has not kept pace with action programs.

A look at the past, showing the path we have followed in arriving at our current position, may also portend future directions. Therefore, we reviewed trends in funding for research and related activities during the 1970's. Our analysis looked first at the national and international scene, then narrowed to the forestry sector, and finally focused on forestry research—more particularly on Forest Service Research.

National Research and Development Funding[10]

Until recently, the trend of national expenditures for R&D has been downward (National Science Board 1977). Expenditures peaked at $30 billion in 1968. Since then, expenditures have decreased about $1 billion in 1972 constant dollars. The Federal Government still is the biggest provider of funds for R&D, but non-Federal sources are assuming more of the R&D job. In 1965, Federal sources provided for 65 percent of the national R&D funds compared to industry's 33 percent. In 1976, the proportion was Federal—53 percent, and industry—43 percent. As a fraction of the Federal budget, R&D funds have declined substantially to 6 percent in 1976 from a high of 13 percent in 1965. President Carter's (1979a) budget message and the USDA's budget would indicate that Federal funding for research is rising again.

The character of national R&D has remained unchanged for two decades (National Science Foundation 1978a). Developmental efforts, predominately related to defense and space, equal about two-thirds of the expenditures. Applied research takes about one-quarter, and basic research, only about one-tenth. The national trend is for reduced Federal funding for development as industry provides more funding.

Other developed countries are still increasing their relative investments in R&D (National Science Board 1977). As a percent of gross national product (GNP), funding for R&D had declined in the United States from a peak of about 3 percent during the 1960's, when we exceeded the funding of any other country, to a current level of about 2.2 percent. Meanwhile, the U.S.S.R., Japan, the Federal Republic of Germany, and the United Kingdom are steadily increasing their percentages. Noteworthy is the world leadership during the 1970's of the U.S.S.R., which has a national expenditure for R&D exceeding 3 percent.

If the proportion that "timber" GNP (Phelps 1980) is to total GNP were reflected in distribution of national R&D expenditures, then investments for timber-related R&D should have been 10 times greater, or about $1,178 billion, in 1972. A tenfold increase in R&D would result if forestry R&D investments were about 2 percent of the forestry GNP, an intermediate position among other industries. Even comparison with the other resource-based industries and industries using forest products would call for an increase of forestry research of three to four times the current levels.

Forestry Research and Development Funding

National expenditures for forestry R&D are estimated at about $280 million in FY 1977 and $331 million in FY 1978 (fig. 14). Sullivan (1977) estimated for 1975 that $217 million were spent on forestry R&D: about 51 percent by industry; 42 percent by Federal agencies; and 7 percent by States. The Federal funds were provided by the Forest Service (36 percent), other agencies in the USDA (3 percent), and all others (3 percent). Lacking recent data on expenditures by industry, we assumed that from 1975 to 1978 industrial expenditures increased proportionally. During that period States and Federal agencies other than the USDA also increased their funding.

Industrial forestry research aims at appropriable products and processes rather than inappropriable management of lands and resources. Of the estimated $169 million in industrial R&D in the forestry sector in FY 1978, probably 75 to 80 percent was spent for new products and processes. Significant expenditures are limited to development for short-term, profit-motivated objectives. Industry's expenditures for R&D related to manage-

[10]The team responsible for tasks contributing to this and the next three sections was led by Dixie R. Smith (RM) and included Billie Bohannon (FPL) and Michael A. Lennartz (SE).

ment of lands and resources probably were in the range of $35 to $45 million.

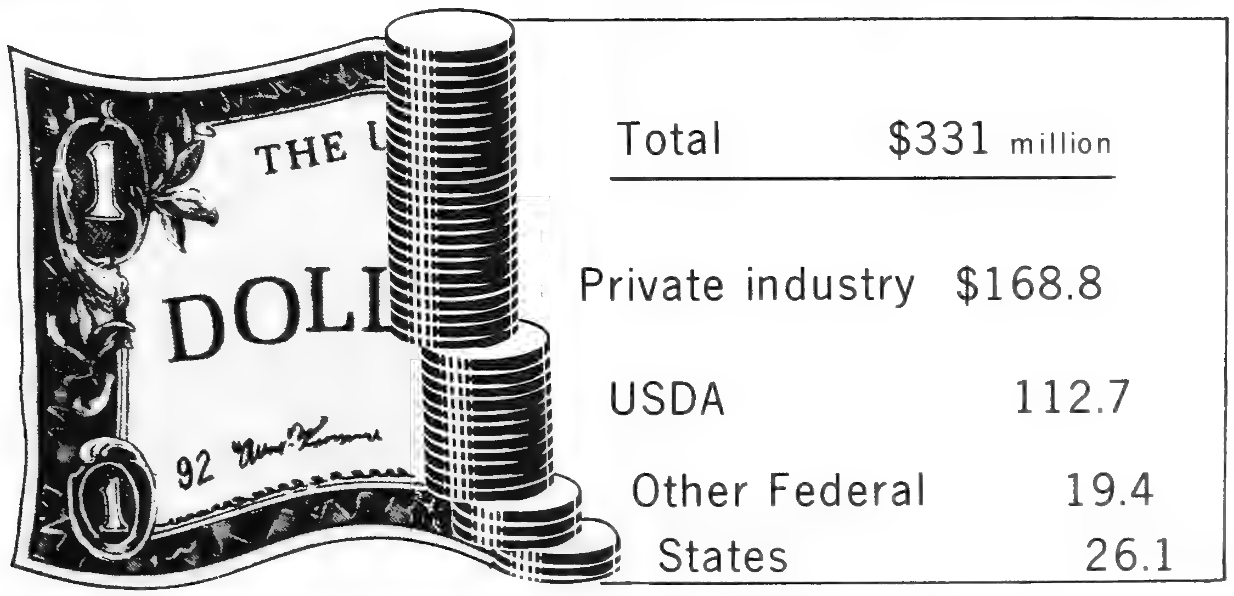
Forestry-related industries rank among the lowest major industries in expenditures for R&D (fig. 15, Anon. 1976b). Office equipment and instrument industries commonly invest in R&D at a rate equivalent to 5 to 6 percent of sales; leisure—1.7 percent; building materials—1.2 percent; containers—1.1 percent; paper—0.8 percent; steel—0.6 percent; food—0.5 percent; and publishing—0.2 percent of sales. The forestry R&D investment amounts to less than 0.2 percent of the total value of timber-based products and services (Phelps 1980). Similarily, research on wildlife, fish, and game constitutes only about 0.2 percent of sportsmen's expenditures for hunting and freshwater fishing.

The relationship between expenditures for forestry R&D and for management of forest and land resources is clearly imbalanced. For example, the national expenditures for timber management research equal about 6 percent of the national expenditures for the management of timber resources on all forest lands. For wildlife research, the expenditures are about 6 percent of all national expenditures for wildlife management (Jahn and Trefithen 1978). For fire research, the level of expenditure is about 2 percent of that for fire management on all wildlands. For range management research, the expenditure is about 0.3 percent of the expenditures for the management of all rangelands in the Nation.

Forestry research represents a minute fraction of the Federal expenditures for R&D (table 12, National Science Foundation 1978b). In FY 1977, total Federal R&D expenditures were an estimated $24 billion. The Federal expenditures for forestry-related research amounted to about $115 million—less than 0.5 percent of the total Federal expenditure for R&D. Surprisingly, forestry research comprised: only 15 percent of Federal expenditures for research on natural resources; less than 5 percent of Federal expenditures directed towards understanding the environment; but more than 20 percent of Federal expenditures for research on economic growth and productivity.

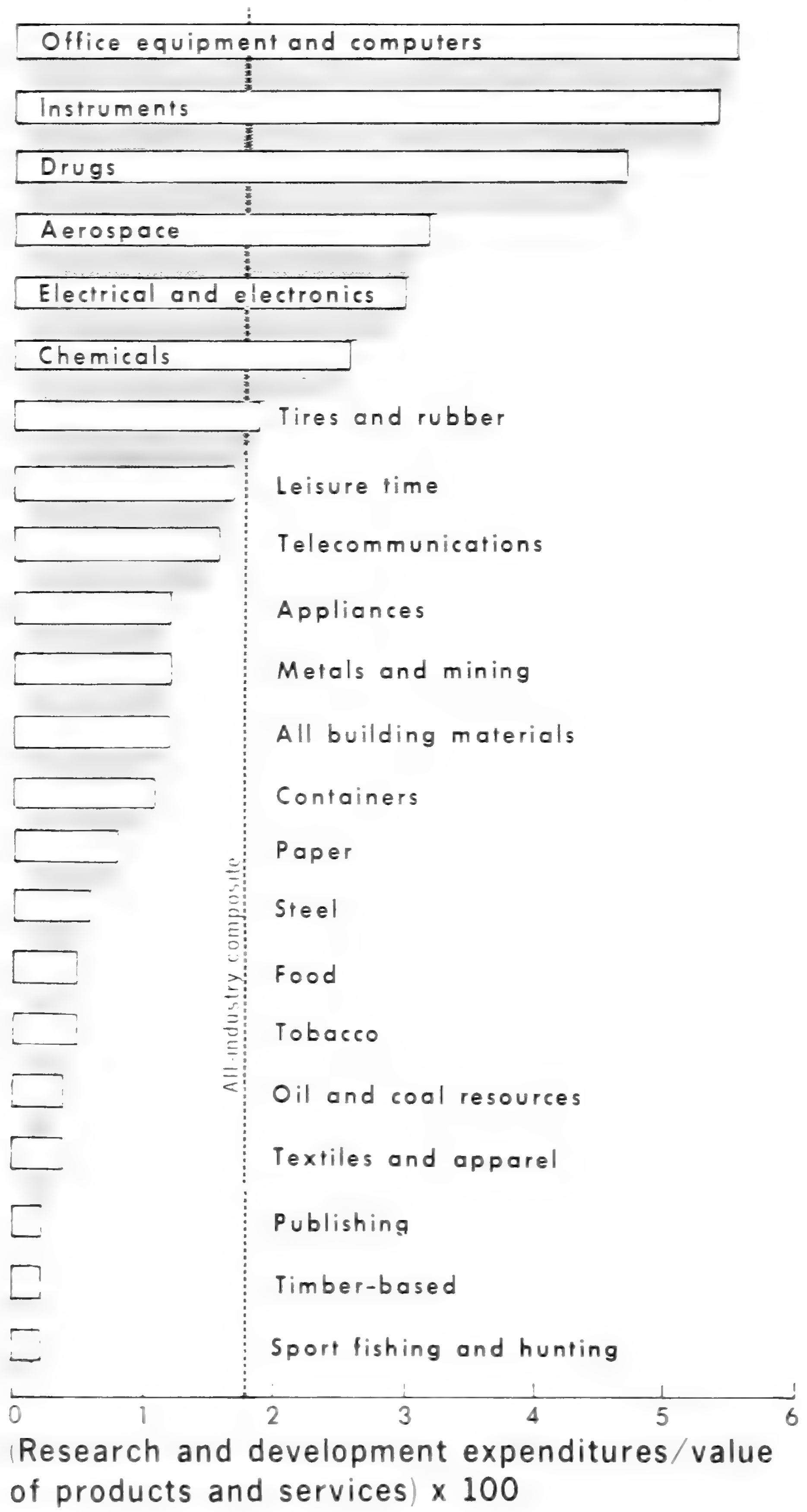
In spite of increasing demands for forestry outputs and concerns about forest environments, the low priority placed on forestry relative to other topics for research has remained unchanged over the past decade.

Figure 14



Funds from private industry accounted for more than half the expenditures for forestry research in fiscal year 1978.

Figure 15



Expenditures for research and development in proportion to the value of products and services are comparatively small for timber-based industries.

Table 12—*Federal obligations for research and development in forestry and related functions, fiscal years 1969-1979*[1]

Function, subfunction and agency program	Fiscal year										
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978 (est.)	1979 (est.)
	Dollars (millions)										
Understanding, describing, and predicting the environment:											
Forest Service	3.1	3.5	3.7	4.9	7.0	7.5	8.1	8.1	8.5	9.3	9.0
Other forestry[2]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All other	111.5	108.6	148.8	169.9	217.6	227.8	232.2	252.4	259.6	280.1	307.8
Natural Resources:											
Forest Service	24.9	27.4	29.5	35.7	36.6	42.5	53.7	55.1	64.1	76.9	73.2
Other forestry[2]	3.4	3.9	4.7	5.0	4.9	8.0	9.3	9.8	10.7	12.2	11.7
All other	171.0	202.7	287.1	310.5	296.2	281.8	335.4	367.7	425.0	519.3	558.8
Economic growth and productivity:											
Forest Service	10.5	11.4	12.4	13.7	14.0	14.7	15.4	15.3	16.9	19.7	19.8
Other forestry[2]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
All other	45.3	68.6	80.5	43.8	53.0	51.7	46.9	61.9	68.9	70.1	81.0

[1] Source: National Science Foundation (1978b).

[2] Includes Cooperative Forestry Research (CSRS) and Cooperative Forest Service Research, U.S. Department of Agriculture; excludes Forest Service Research done in other countries.

Table 13—*Total appropriations to Forest Service for research and development, fiscal years 1969-1979*

Research activity	Fiscal year										
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
	Dollars (millions)										
Timber management	9.32	10.07	11.23	11.75	12.00	13.09	14.54	15.08	15.75	17.96	19.75
Forest products and utilization	8.17	9.13	9.92	10.52	10.72	11.27	11.93	12.81	13.41	14.23	13.52
Forest engineering											
Forest products marketing	1.56	1.70	1.98	2.05	2.04	2.17	2.23	2.29	2.37	2.51	2.33
Total	19.05	20.90	23.13	24.42	24.76	26.53	28.70	30.18	31.53	34.70	35.60
Watershed management	4.03	4.42	4.83	6.15	6.50	7.71	8.53	7.71	8.03	8.83	9.67
Range management and fisheries	1.32	1.45	1.53	1.61	1.59	2.21	2.09	2.18	2.24	2.61	2.56
Wildlife/habitat	1.02	1.26	1.43	1.91	2.28	2.03	2.98	3.39	4.24	5.33	6.43
Forest recreation	0.86	0.92	1.04	1.07	1.12	1.33	1.25	1.50	1.56	3.08	3.30
Forest fire	3.42	3.88	4.07	5.13	7.66	7.84	8.21	8.38	8.68	8.97	9.73
Forest insect and disease	6.96	7.74	8.13	9.41	10.14	10.76	17.88	18.96	19.76	20.17	21.46
Total	10.38	11.62	12.20	14.54	17.80	18.60	26.09	27.34	28.44	29.14	31.19
Forest survey	2.37	2.73	3.34	3.48	3.47	3.65	3.80	5.46	9.14	13.20	14.10
Forest economics	1.03	1.12	1.37	1.42	1.44	1.49	1.53	1.57	1.62	2.00	4.95
Total	3.40	3.85	4.71	4.90	4.91	5.14	5.33	7.03	10.76	15.20	19.05
Surface Environment and Mining (SEAM)							2.26	2.60	2.60	2.64	3.16
Total	40.06	44.42	48.87	54.60	58.96	63.78	77.61	82.28	89.79	101.49	110.95

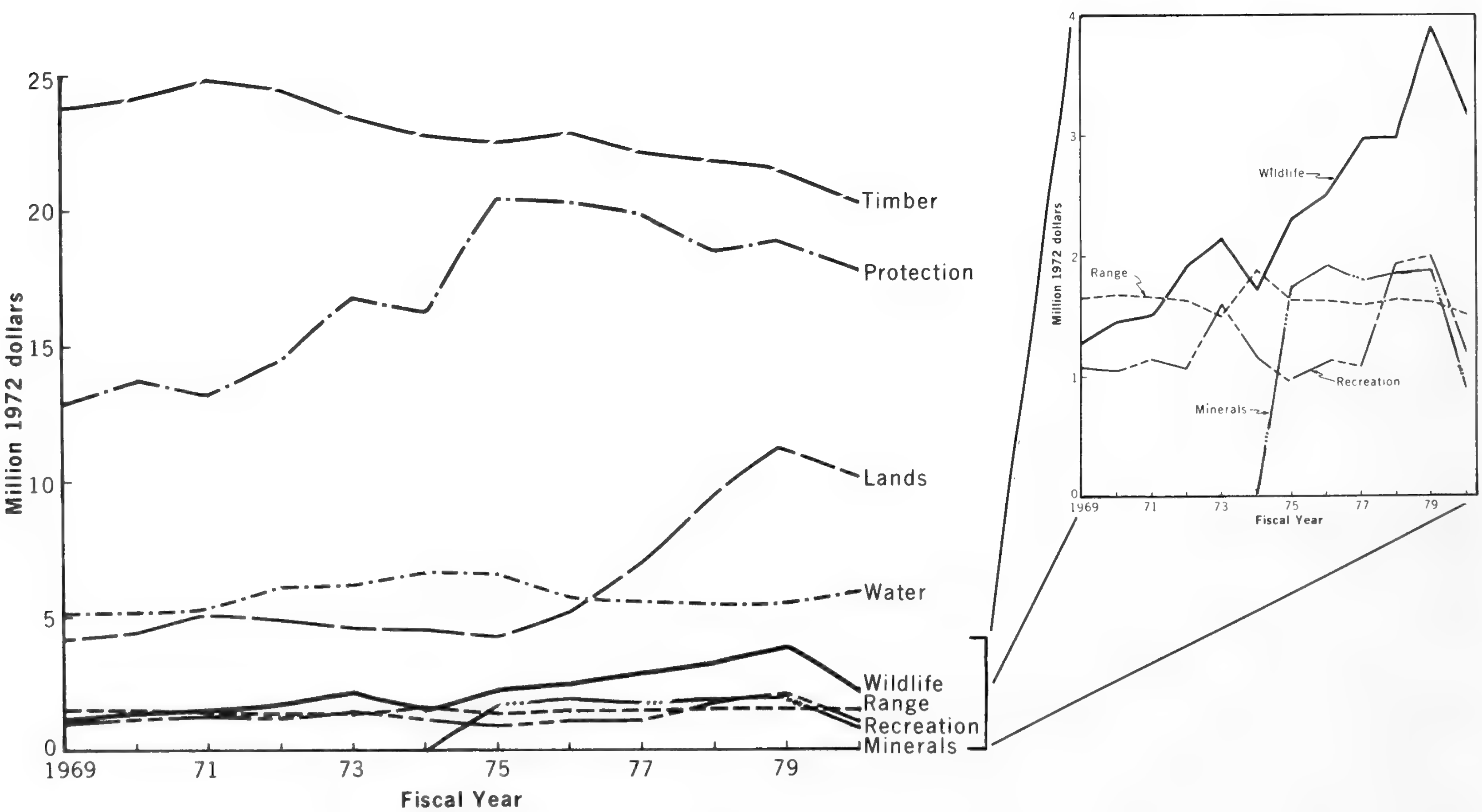
The Magnitude of Forestry

Compiling data on funding for forestry and forestry research brought us many estimates, claims, questions, and problems. On the one hand, it is asserted that forestry research is too big! On the other hand, it is asserted that it is not big enough! How big is it then? How large should forestry research be? We learned to respond with our own questions: What is forestry? And how big is it?

The sideboards on forestry and forestry research are flexible, even elastic. Definitions depend upon the use to which they will be put. Organizations and practitioners performing forestry-related work draw different bounds. They describe lands, resources, and values in different terms. Consequently definitions and data are needed before today's questions can be answered.

Resources, industries, and research related to timber in the United States are most easily defined. They have been studied extensively and pose few problems. But the problems become insurmountable when an attempt is made to get a handle on water, range, wildlife, and recreational aspects of forestry. The RPA Assessment may provide assistance in the future in understanding the status of these renewable natural resources. We foresee great difficulty in partitioning and breaking out the "forestry portion" of research devoted to these resources. Nevertheless, this is a task that needs undertaking.

Figure 16



Appropriations when shown in constant dollars have increased for some Forest Service Research activities but decreased for others.

Forest Service Research Funding

Forest Service expenditures for R&D have increased $16 million or 31 percent since 1969, in constant 1972 dollars (table 13). The increased expenditures were largely for: three large insect programs ($4 million), forest survey ($5 million), and Surface Environment and Mining Program (SEAM) ($1.7 million). Smaller increases were appropriated for endangered species and anadromous fish ($1 million), forest fire ($1 million), watershed ($0.5 million), and urban forestry ($1 million).

Most important, all increases for Forest Service Research were targeted, primarily by the Congress, for specific problems and locations. Gradually increasing costs, across-the-board, were not met. Inflation has continually eroded capabilities for conducting research. One evidence of inflation's effect (reinforced by ceilings on employment) is that while funds have steadily increased scientist-years supported by Forest Service Research have held relatively constant:

Fiscal Year	*Scientist-Years*
1966	914
1968	921
1970	951
1972	959
1974	947
1976	932
1978	955
1979	979

The growth and decline of Forest Service R&D programs varied greatly among the RPA elements (fig. 16, table 13). In constant dollars, timber management research, range management research, and wildland recreation research actually had less money in 1978 than in 1969. The greatest program expansion took place in the protection element (insects and diseases) and in the lands element (forest survey). Much smaller increases occurred in the wildlife and fish, minerals, recreation, and wilderness elements.

Under the 1975 RPA program, the budget for Forest Service Research did not keep pace with that for the National Forests (table 14). The National Forest System budget for land management increased 123 percent during the period 1975 through 1979. In contrast, the budgetary increase for Research during that period was only 43 percent. Meanwhile, simply to maintain the status quo required an increase of 29 percent because of inflation. Therefore, the real growth in Research during the last 5 years was only about 10 to 15 percent; whereas, the real growth for the National Forest System was almost 100 percent. If Research were to have maintained its 1975 relationship of service to the National Forests, the FY 1979 appropriation for R&D should have been $168.2 million; instead, it was $108.2 million. The accumulative shortfall for Research—$60 million—is reflected in the growing incapability of Research to meet the demands and needs of land management on the National Forests and other Federal and State lands.

Forest Service Research under the RPA program, 1975 to 1979, also fell behind agricultural and forestry-related research (fig. 17). Appropriations for research by the Fish and Wildlife Service, for example, increased 79 percent for research alone, and 99 percent for research and the related work of the Office of Biological Services, U.S. Department of Interior. Meanwhile, during that period, funding for Forest Service Research was increased by about 43 percent. Within the USDA, other research programs fared far better than Forest Service Research. Within SEA, funding for Cooperative Research, a formula-funded activity, was up 72 percent, and that for agricultural research was up 57 percent. Expenditures for economics research (ESCS) were up 44 percent during the period. Furthermore in FY 1980 all other research in USDA grew substantially, up $53.9 million or 8.9 percent, while Forest Service Research shrank, down $2.1 million or 1.9 percent.

Table 14—*Changes in Forest Service appropriations under the Renewable Resources Planning Act for related activities of National Forest System (NFS) and Research, 1975, 1979*

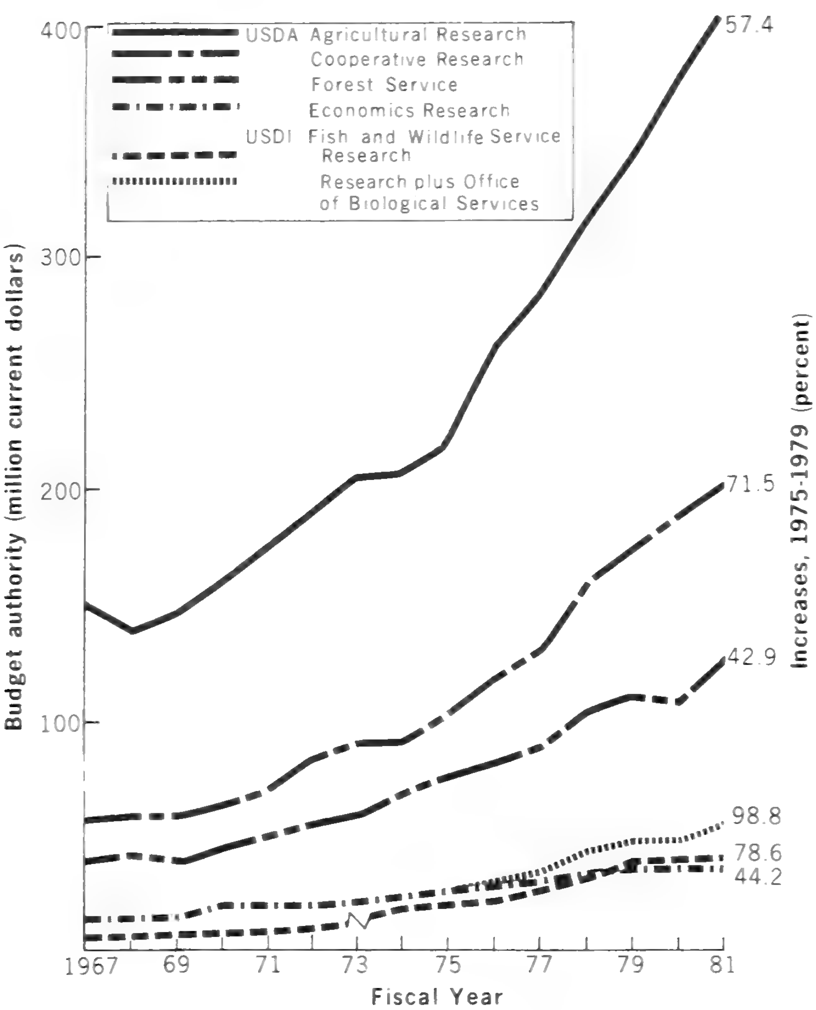
Activities	Branch	1975	1979	Change
		Dollars (thousands)		*Pct.*
Timber	NFS	119,029	257,255	+116
	Res.[1]	25,072	34,925	+ 39
Soil and Water	NFS	15,151	35,652	+135
	Res.[2]	7,227	9,600	+ 33
Wildlife and Fish	NFS	9,190	28,960	+215
	Res.	3,230	6,248	+ 93
Range	NFS	16,391	31,934	+ 95
	Res.	1,841	2,503	+ 36
Recreation	NFS	46,248	91,962	+ 99
	Res.[3]	1,235	2,183	+ 77
Minerals	NFS	3,601	11,934	+231
	Res.	1,700	3,122	+ 84
Fire Protection	NFS	36,257	132,993	+267
	Res.	7,767	9,529	+ 23
Insects and Diseases	NFS	11,242	23,800	+112
	Res.	16,681	20,768	+ 25
Subtotal	NFS	257,109	614,490	+139
	Res.	64,753	88,875	+ 37
Total all activities	NFS	306,119	682,892	+123
	Res.	75,402	108,166	+ 43

[1] Includes timber management research, forest products utilization research, forest engineering research, and forest resources evaluation research.

[2] Includes only watershed management research.

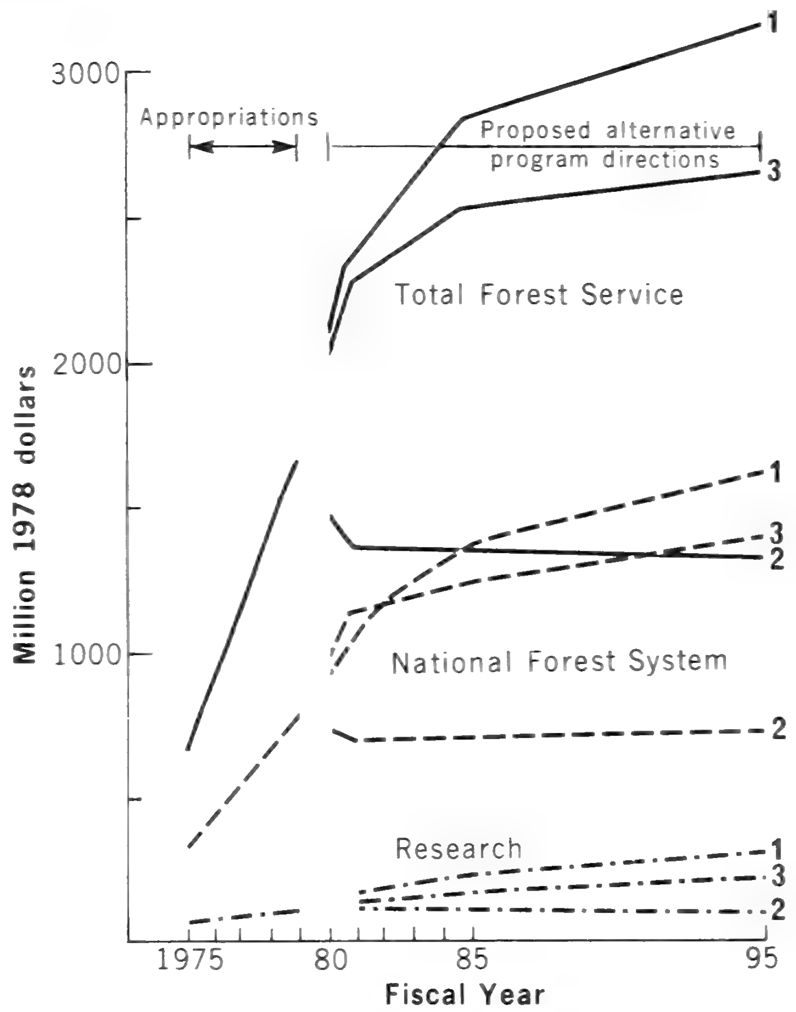
[3] Excludes urban forestry.

Figure 17



Trends in budget authority for research by four agencies in the U.S. Department of Agriculture, and by the Fish and Wildlife Service, U.S. Department of Interior.

Figure 18



Appropriations achieved for the Forest Service and its Research and National Forest System branches, and proposed alternative program directions (APD) under the Forest and Rangeland Renewable Resources Planning Act.

New Direction for Research

What happened so that Forest Service Research did not prosper under the RPA? In 1975, the Forest Service decided the course to be followed during the first 5 years under the RPA. Research was allowed only a slow rate of increase, whereas the National Forest System was allowed a much faster rate of increase (fig. 18). This decision in 1975 radically changed the long-standing position of research within the Forest Service (fig. 19, table 15). During at least two decades before 1975, appropriations for Research averaged:

- more than 20 percent of appropriations for National Forest land management; and
- more than 10 percent of total appropriations for the Forest Service.

During the decade 1966-75, appropriations for research held steady at:

- about 22.5 percent of appropriations for National Forest land management; and
- about 11.8 percent of total appropriations for the Forest Service.

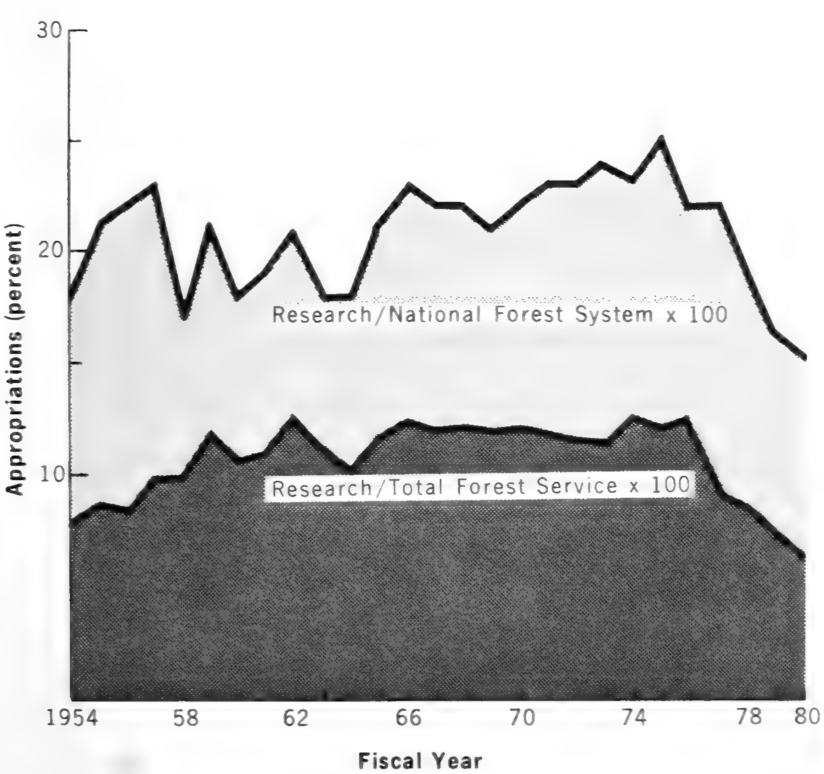
After 1975, Research rapidly lost ground within the Forest Service. Appropriations for Research in FY 1979 had fallen to:

- 16 percent of appropriations for National Forest land management; and
- 7.5 percent of total appropriations for the Forest Service.

Appropriations for FY 1980 dropped Forest Service Research another notch to 5.9 percent of total appropriations for the Forest Service. This decline is particularly noticeable in the light both of increases granted other research agencies in that budget and of President Carter's (1979b) message on science and technology. Research in the Forest Service since 1975 has not enjoyed the "continuity and consistency in . . . support . . . the necessary assurances and commitments . . . (or the) real growth . . ." of which the President wrote.

The lower relative position of Research within the Forest Service in FY 1979 was projected into the future as the RPA's alternative program directions for 1981, 1985, and 1995 (fig. 18). At either the highest or lowest alternative program direction levels, research would share funding about as it does now. At least, the decline in funding would stop. Unexplained however, is why Research was not projected either to decline more or rebound somewhat. One purpose of this report is to provide information and criteria by which alternative program directions can be evaluated as a basis for decisions.

Figure 19



Trend in relation between appropriations to Forest Service Research and to the National Forest System and to the entire agency.

Balance Within the Research Program[11]

Forest Service Research today was shaped by a long chronology of events influenced by many factors. If one could step back from the budget-making and appropriation processes, how might one evaluate the development of the current program? How could its balance be improved? These questions were approached from three viewpoints: (a) geographic balance; (b) functional balance; and (c) structural balance.

Distribution of funding among Stations and broad geographic regions has been relatively stable, despite significant dollar increases and some decreases (table 16). Most notable

[11]The team responsible for the task was comprised of Carter B. Gibbs (INT) and Benjamin Spada (PSW).

Table 15—*Initial appropriations for Forest Service's Research and National Forest System branches, 1954-1981*

Fiscal year	(1) Research	(2) NFS-forest land management	(1)/(2)	(3) Total Forest Service	(1)/(3)
	Dollars (millions)		*Pct.*	*Dollars (M)*	*Pct.*
1954	5.350	29.716	18.0	66.964	7.98
1955	6.539	30.490	21.5	75.185	8.69
1956	7.754	35.512	21.8	91.025	8.51
1957	10.000	44.301	22.6	101.671	9.83
1958	11.835	68.750	17.2	119.926	9.86
1959	15.678	75.107	20.9	130.265	12.03
1960	14.026	77.816	18.0	130.930	10.71
1961	17.332	92.160	18.8	154.287	11.23
1962	26.368	128.000	20.6	209.128	12.60
1963	24.835	139.400	17.8	223.295	11.12
1964	25.893	147.312	17.6	254.368	10.17
1965	31.685	149.944	21.1	270.804	11.70
1966	36.689	162.318	22.6	296.972	12.35
1967	37.821	173.850	21.8	332.878	11.36
1968	41.657	185.618	22.4	358.806	11.60
1969	38.866	184.444	21.1	335.923	11.56
1970	42.137	192.810	21.9	306.026	11.70
1971	45.591	199.617	22.8	401.395	11.35
1972	54.325	238.678	22.8	496.610	10.93
1973	61.143	255.604	23.9	562.229	10.87
1974	60.160	257.461	23.4	477.932	12.58
1975	75.402	306.119	24.6	630.675	11.95
1976	80.355	365.821	22.0	651.090	12.34
1977	87.087	397.151	21.9	954.874	9.12
1978	101.488	533.918	19.0	1,187.917	8.54
1979	108.166	682.892	15.8	1,420.095	7.61
1980	108.795	700.515	15.5	1,494.848	7.28
1981[1]	124.100	798.933	15.5	1,454.236	8.53
APD 1[2]	174.900	1,094.400	15.9	2,316.800	7.5
APD 3	153.800	1,103.800	13.9	2,281.800	6.7
APD 2	105.400	648.700	16.2	1,361.600	7.7

[1] Revised President's Budget.

[2] Alternative Program Directions in Draft Program for 1981.

are the growth in funding for two Stations (Pacific Northwest, +1.9 percent; and Northeast, +1.6 percent) and the decline for two Stations (Pacific Southwest, −2.6 percent; and Southern, −1.6 percent).

Criteria for evaluating the need for and impacts of changes in geographic distribution of research funding were identified. They included: population, areas and values of commercial forest land and of forest and rangeland, recreational use, and scarcity and quality of water. We did not come up with practical ways, however, of using these multiple criteria to alter the current geographic distribution of funding among Stations. Politics, vested interests, tradition, and many other forces befuddle the decisionmaking process.

Funds for various functional activities are imbalanced. For example, functional funding for research has not kept pace with functional increases in funding for National Forest Systems (table 14). Expanding action programs, such as wildlife management, often require technology that is not available. Some functional areas of research, such as timber and range management and wildland recreation, are actually receiving fewer constant dollars than 10 years ago. This difference exists despite rapid growth in demand for outputs from these functional areas on all forest and rangelands.

If the budget-making process permitted, significant adjustments should be made among the functional areas of research in order to improve the balance (table 17). At the national level, some functions most demanding of increases are economics and marketing, recreation and environmental values, watershed management, and timber management. Those activities least demanding of increases, but needing some, are protection from fire, insects, and diseases.

Looking simultaneously at geographic and functional distribution of programs disclosed some severe imbalances (table 18). The only data available were for functional allotments of funds to Regions of the National Forest System and to Research Stations. We compared allotments for FY's 1975 and 1979. These data provided comparisons among geographic regions and functions in the western United States. The data should not be used to compare the West with either the South or the North

Table 16—*Geographic distribution of funds for Forest Service Research, by Region and Experiment Station*

Region and Station	Fiscal Year 1975 Without FPL	Fiscal Year 1975 With FPL	Fiscal Year 1979[1] Without FPL	Fiscal Year 1979[1] With FPL
	Percent			
Pacific Coast:				
Pacific Northwest	13.96	12.31	15.87	14.14
Pacific Southwest	12.54	11.06	9.97	8.88
Total	26.50	23.37	25.84	23.02
Rocky Mountains:				
Intermountain	12.38	10.92	12.99	11.57
Rocky Mountain	9.94	8.76	9.88	8.80
Total	22.32	19.68	22.87	20.37
Total Western	48.82	43.05	48.71	43.39
Northern:				
North Central	9.69	8.54	9.89	8.81
Northeastern	15.99	14.10	17.56	15.64
Total	25.68	22.64	27.45	24.45
Southern:				
Southern[2]	13.78	12.15	11.22	10.00
Southeastern	11.72	10.34	12.62	11.24
Total	25.50	22.49	23.84	21.24
Forest Products Laboratory (FPL)	—	11.82	—	10.92
Total	100.00	100.00	100.00	100.00

[1] For fiscal year 1979 each 1 percent of difference equals about $1 million or 10 scientist-years.

[2] Includes Institute for Tropical Forestry, Puerto Rico.

Table 17—*Proposed increase in funds, from fiscal year 1979, for Forest Service Research according to alternative program direction 1, Renewable Resources Planning Act*

Research program and activity	FY 1979 budget	Proposed program[1]	Increase
	Dollars (thousands)		*Pct.*
Multiresource inventory and appraisal	13,798	20,638	49
Timber management	19,187	34,455	80
Forest protection:	30,435	36,029	18
Forest insect and disease research	[2](20,906)	(24,486)	(17)
Forest fire and atmospheric sciences research	(9,529)	(11,543)	(21)
Wood products properties, processing and protection	13,115	22,912	75
Forest engineering	2,279	3,673	61
Watershed management	[3]12,553	25,186	100
Forest, range, wildlife and fisheries habitat	8,751	14,867	70
Recreation and environmental values	3,233	6,821	110
Forest economics and marketing	4,815	10,319	114
Total	108,166	174,900	62

[1] Based on 1980 projections in the Forest Service's National Program of Research for Forests and Associated Rangelands.

[2] Includes funds for spruce budworms, gypsy moth, and southern pine beetle programs.

[3] Includes funds for Surface Mining and Environment (SEAM) programs.

Central/Northeast. In the East, National Forests are less abundant and dominant, as clients for research, than they are in the West. Some examples of severe imbalance are:

- 151-percent increase for timber management in the Intermountain West, but only 26-percent increase for timber management research at the Intermountain Forest and Range Experiment Station
- 121-percent increase for recreation management in California, but only a 24-percent increase for recreation research at the Pacific Southwest Forest and Range Experiment Station
- only token recreation research programs in the South and in the Rocky Mountains, but major recreation action programs in those areas
- 242-percent increase for research on wildlife, range, and fish in Oregon, Washington, and Alaska, but only a 153-percent increase for related management on the National Forests of those states.

One of the several major forces shaping regional differences in the Forest Service research program has been political considerations. As problems and crises arise, vested interest groups seek and gain political support. Increased money is available for certain research activities, but little or no money is available for others. Because of political considerations needed investments and funding for research have not been realized. The political process certainly will continue to be a major force in shaping future research programs; however, other factors discussed earlier, as well as obligations and needs of localized action programs, should play a stronger role in shaping future regional research programs. RPA should be the place for objective, apolitical decisions by managers to achieve desirable balance among Stations and elements of the Research program.

The structural balance in Forest Service Research has remained surprisingly constant. The balance among basic research (30 percent), applied research (65 percent), and development (5 percent) has remained stable for many years. Perhaps this stability is more a result of definition of the terms than of a conscious decision to maintain balance. Also it may reflect more a desire of management to control the balance of research than of any real balance within the research program. Agencies also differ in their interpretation of these terms. Because emphasis on basic research needs to be continued and expanded, the proper use of these terms and the current balance in research in USDA merit comprehensive study.

Whereas, the Servicewide balance has been maintained, Stations show surprising differences in proportions of basic, applied, and developmental effort (table 19). Most Stations are close to the 30 percent long-term average for basic research. Forest Products Laboratory, as expected, is high (44.2 percent) in basic research, and the Intermountain (16.6 percent) and Rocky Mountain Stations (20.8 percent) are unexpectedly low in basic research. Stations vary in the amount of applied research from 55 to 71 percent.

Stations show startling differences in developmental efforts. Three Western Stations—Pacific Southwest, Intermountain, and Rocky Mountain—are highest with 12 to 13 percent developmental research. As expected and following its charter, the Forest Products Laboratory has only 1 percent of developmental research. Most surprising, Southern Station is lowest of all (0.6 percent) in developmental effort; whereas, its companion Southeastern Station (9 percent) is somewhat above average.

The extramural component of Forest Service Research has grown slowly during the past decade (fig. 11). Direct obligations now equal about 11 percent of appropriations. An additional 9 percent of appropriations is spent intramurally for research management and support services, and for scientific leadership in cooperative research. Further increases or decreases in extramural research should be based on need, such as for competitive grants or constraints on employment, rather than on some *a priori* level for extramural research.

Table 18—*Changes in allocations[1] to Forest Service Regions and adjacent Experiment Stations for five comparable budgetary activities*

Region/ Station	Timber[2]			Water			Wildlife, Range, and Fisheries			Range			Recreation[3]		
	1975	1979	Change	1975	1979	Change	1975	1979	Change	1975	1979	Change	1975	1979	Change
	Dollars (M)		*Pct.*	*Dollars (M)*		*Pct.*	*Dollars (M)*		*Pct.*	*Dollars (M)*		*Pct.*	*Dollars (M)*		*Pct.*
Pacific Northwest and Alaska Regions/	34,618	79,023	+128	2,804	9,086	+224	3,755	9,504	+153	1,770	3,972	+124	7,572	15,574	+106
Pacific Northwest	1,690	2,455	+ 45	950	1,468	+ 54	587	2,010	+242	431	582	+ 35	121	281	+132
Pacific Southwest/	17,402	34,793	+100	2,342	5,712	+143	2,188	6,212	+184	1,229	2,657	+116	9,726	21,527	+121
Pacific Southwest	1,028	1,347	+ 31	851	1,080	+ 27	339	911	+168	172	233	+ 35	187	232	+ 24
Northern and Intermountain Regions/	20,580	51,637	+151	3,503	6,735	+ 93	7,867	16,859	+114	5,904	10,950	+ 85	8,848	14,603	+ 65
Intermountain	814	1,027	+ 26	652	908	+ 39	736	1,385	+ 88	569	768	+ 35	162	294	+ 82
Rocky Mountain and Southwestern Regions/	11,376	32,880	+189	2,694	5,777	+114	7,034	14,338	+104	5,640	9,199	+ 63	7,555	15,471	+105
Rocky Mountain	718	988	+ 38	1,962	2,628	+ 34	903	1,632	+ 81	328	442	+ 34	40	142	+255
Eastern Region/	12,252	17,300	+ 41	1,355	2,687	+ 98	1,634	4,767	+191	164	807	+392	4,877	9,065	+ 86
North East and North Central	3,879	5,374	+ 38	1,568	1,926	+ 22	425	896	+111	0	0	—	492	879	+ 79
Southern Region/	19,079	30,415	+ 59	1,482	3,717	+151	1,986	6,338	+219	755	2,563	+229	5,651	11,372	+101
Southern and Southeastern	4,907	7,113	+ 44	786	1,031	+ 31	593	1,188	+100	225	235	+ 4	128	146	+ 14
Regions	115,309	246,048	+113	14,170	33,714	+138	24,464	58,018	+137	15,462	30,148	+ 95	44,239	87,612	+ 98
Stations	13,036	18,304	+ 40	6,770	9,041	+ 33	3,582	8,022	+114	1,725	2,259	+ 31	1,130	1,974	+ 75

[1] All funds appropriated are not allocated to Regions and Stations, so numbers do not agree with those in other tables.

[2] For Regions—includes sales inventories, examinations, reforestation, and stand improvement; for Stations—timber management research only.

[3] Does not include urban forestry research.

Table 19—*Basic, applied, and developmental research at and among Forest Service Experiment Stations and Forest Products Laboratory, fiscal year 1978*

Experiment Station	Kind of research				Basic		Applied		Developmental	
	Basic	Applied	Developmental	Total	Without FPL[1]	With FPL[1]	Without FPL[1]	With FPL[1]	Without FPL[1]	With FPL[1]
	Percent									
Pacific Northwest	35.45	59.57	4.98	100.00	18.38	15.58	14.29	12.95	9.48	9.34
Pacific Southwest	30.20	57.78	12.02	100.00	10.64	9.02	9.42	8.54	15.56	15.33
Intermountain	16.63	70.94	12.43	100.00	7.41	6.28	14.62	13.25	20.33	20.04
Rocky Mountain	20.80	65.80	13.40	100.00	7.02	5.95	10.26	9.30	16.58	16.34
North Central	33.41	62.61	3.98	100.00	10.87	9.21	9.42	8.54	4.75	4.68
Northeastern	33.13	59.17	8.70	100.00	19.01	16.11	16.18	14.67	18.87	18.60
Southeastern	33.54	57.46	9.00	100.00	13.60	11.53	10.77	9.76	13.38	13.19
Southern	28.50	70.88	0.62	100.00	13.07	11.08	15.04	13.63	1.05	1.03
Forest Products Laboratory	44.15	54.87	0.98	100.00	—	15.24	—	9.36	—	1.45
All Units	30.71	62.10	7.19	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: Current Research Information Service, U.S. Department of Agriculture, Washington, D.C., June 17, 1979.

[1] Forest Products Laboratory.

RPA: Draft Assessment and Program Directions[12]

In March 1979, the Forest Service released for review, drafts of two documents: "An Assessment of the Forest and Rangeland Situation in the United States" and "Alternative Program Directions, 1981-2030." These drafts provided the first look for Forest Service field officers and the public at the assessment and proposed alternative levels for programs.

The RPA requires that the public be informed about and be actively involved in formulating major Forest Service programs. One key to the success of this planning process is obtaining the views and opinions of the public.

During spring 1979, the Forest Service circulated the "Assessment" and "Program" reports for public review. This effort elicited 1,625 responses. In June 1979, interdisciplinary teams from Forest Service Regions, State and Private Forestry units, Experiment Stations, and the Washington Office reviewed and analyzed these comments.

An estimated 20 percent of the 1,625 respondents commented on Forest Service Research. Most of the comments concerned specific areas of research and supported increased research effort and program funding. Less than 5 percent of the respondents opposed additional emphasis in research, but did not elaborate or offer any reasons. Areas of increased research emphasis most frequently proposed were:

1. Improve production of forest biomass and use of wood fiber as a cost-effective energy source while preserving other market and nonmarket values;
2. Increase research to maximize habitat for wildlife to enhance grazing for livestock, and to improve habitat for fish, especially to maintain water quality and flow;
3. Improve timber and forest product utilization in order to extend wood supplies—including techniques for harvesting and processing, conservation in construction without loss of strength, and increased life for wood in use;
4. Improve silvicultural practices to increase growth, quality and yields of timber;
5. Increase economics research dealing with timber supply and demand and related data collection and evaluations;
6. Expand opportunities to utilize the Nation's hardwoods; increase research to solve unique silvicultural and management problems associated with second growth hardwoods; and improve management techniques to enhance nonmarket values from eastern hardwood forests;
7. Develop nonchemical and biological controls to replace herbicides and pesticides which are determined to be environmentally unsafe;
8. Intensify monitoring and evaluation of effects of chemicals on ecosystems;
9. Increase basic research to ensure and sustain long-term achievements in silviculture, pulp and paper making, energy and chemicals from wood, biological conversion of wood, water and air quality, range, biological control of pests, adhesives and bonding, timber quality, growth and yield, photosynthetic reactions, and forest genetics;
10. Provide more effective technology transfer and maximum use of existing technology before starting new research;
11. Provide research support to increase production of timber from nonindustrial private lands;
12. Expand research to support emphasis on both market and nonmarket goods and services on National Forests in the eastern United States in order to meet needs of nearby population centers;
13. Measure effects of air pollution on vegetation and wildlife;
14. Improve soil stability;
15. Monitor nonpoint source pollution;
16. Establish more research natural areas;
17. Study long-term effects of implementing NFMA regulations;
18. Broaden wilderness research beyond recreation-visitor problems;
19. Minimize impacts on other resources of exploring for and extracting minerals;
20. Increase research on fire management, including FIRESCOPE;
21. Develop methodology and data bases to assure consistency between resources;
22. Increase research on water quality and quantity; and
23. Improve habitat for anadromous fish, with special emphasis on salmon.

Public preference for the RPA alternative program directions was variable. Most respondents seemed to favor APD 1 and 3 or modified versions thereof. Supporters for APD 1, the highest level, cited the proposed research program with emphasis on market values as one reason for favoring that alternative. The balance of research on market and nonmarket values and the level of research proposed for the mid-level of APD 3 were important to backers of that alternative. Those who supported the intermediate level of APD 4 found the proposed research program to their liking because it supported increased nonmarket values from National Forest lands and increased market values from private lands.

The public responses covering Forest Service Research programs and study opportunities are by no means all-inclusive. Although these responses represent a wide-spectrum of opportunities in research, they highlight those situations which people perceive as being most important to them.

[12]The individual responsible for contributing this section was Rodney G. Larson (FPL).

Research in the RPA Process: A Forward Look

Before making this effort, we recognized many gaps in our information base. As a result of the effort, many more needs for definitive information, based upon detailed study and analyses, became apparent. Research should seek to supply this information in the near future. We need answers to questions not only for the RPA process but, more important, for our understanding and management of Research in the Forest Service.

A comprehensive assessment of forestry technology is now our foremost need. The RPA called for an assessment of the status of forestry natural resources, but it failed to mention or require an assessment of the adequacy of technology for managing and utilizing those resources. Consideration might even be given to a technical amendment to either that Act or to the Renewable Resources Research Act so as to require periodic assessments of forestry technology. But legislative authority is not really needed because we already are obliged to identify needs for new knowledge and methodology to improve the technological basis for managing and utilizing forests. As we identify needs for research and plan research programs, we are approaching an assessment of technology. Perhaps in 2 or 3 years, a full-blown technology assessment for forestry can be conducted.

In recent years, Forest Service Research has significantly improved its evaluations of the productivity and accomplishments of forestry research programs. Evidence of these improvements include: the Research Work Unit attainment reporting system, the use of management by objectives in Experiment Stations, and this first report of hindsight evaluations of costs and benefits from innovations resulting from Forest Service Research. We should observe other research organizations striving to improve their evaluations. Promising approaches should be pilot tested, and the most promising should be demonstrated. Ultimately, we should internalize a regular process of evaluations of productivity and accomplishments of forestry research programs. This effort should not only include the Forest Service, but also the research programs at forestry schools conducted by universities and states.

Emerging from our many tasks were the first criteria and process for selecting among alternative research programs. These criteria need to be improved and the process sharpened. The outcome should be an improved basis for decisions which previously have been made almost intuitively because of the lack of information, the vagueness of criteria, and the lack of a process to provide basic information.

During this effort, team members repeatedly asked unanswerable questions and identified information that would be useful to have. These questions needing answers emerged from our inquiries.

Trends in Research and Related Areas

1. What is or should be the size of forestry research in relation to all forestry activities and to forestry functions?
2. How large is "big forestry," particularly with respect to watersheds, wildlife and fish, and recreation?
3. What is the nature of the involvement in forestry and forestry-related research of industry, and of Federal agencies in Executive Departments other than the USDA—i.e., who does such research and at what expenditures?
4. Are Forest Service Research statistics credible as to the proportions of our effort in basic research, applied research, and development, and are our statistics comparable to those generated by other Federal research agencies?

Outputs, Benefits and Costs

5. Can innovations be adapted as the basic outputs for forestry research?
6. Can attainments, other than publications, be accounted for and valued?
7. What are the internal rates of return from a broad sample of past innovations having quantifiable benefits (*post facto*)?
8. What would be the expected rates of return, assuming success, for innovations yielding quantifiable benefits in the future (*ex ante*)?
9. Can programmatic hindsight analyses be so structured as to be more useful in predicting the future?
10. How should we handle nonquantifiable benefits relating to about two-thirds of all innovations resulting from FS research?

Users and Clients

11. How numerous are the various users of forestry research?
12. How should research and extension count users of their services?
13. What is the redundancy among Station mailing lists. How many users are contacted through mailings to organizational addresses?
14. What numbers of users are contacted by each kind of output or from forestry research units?
15. How do professionals in various disciplines judge Forest Service Research in comparison to other research organizations? How do they value our outputs?

Criteria for Programmatic Decisions

16. What is the feasibility for greatly expanding Forest Service extramural research programs through grants, contracts, R&D programs, and "captive laboratories?"

17. What would be the realizable supply of scientists for a greatly expanded Forest Service Research Program? What specialties are in shortest supply and need attention?

18. What special research plans and programs are needed or appropriate for functions and activities in addition to those already available?

19. What adjustments in allocations of increased funding to activities and Stations would be desirable considering current imbalances?

Conclusions

This taking of stock in 1979 by Forest Service Research managers resulted in the first set of criteria for evaluating alternatives for research programs in the agency. These criteria were developed because of a need to respond to the Forest and Rangeland Renewable Resources Planning Act, which calls for decisions on several issues affecting forestry research. And the decisions required assembly and display of data and the definition of criteria on which the decisions should be based. The four criteria developed are:

- Response to needs primarily national regional, or special needs for which technology is inadequate. Needs are generated by legislative mandate, expressed by users of technology, and identified by scientists. An analysis of the breadth and diversity of the clientele for forestry research also indicates the need for such research.
- Contributions to productivity and other returns including both quantifiable and nonquantifiable benefits. Improvements in technology, resulting from research, contribute 30 to 70 percent of the growth in productivity. Internal rates of return from several areas of agricultural research are in the range of 30 to 40 percent. The first comprehensive hindsight analyses show substantial outputs and benefits from Forest Service Research.
- Response to national policies, particularly those related to science and technology and enunciated by the branches of the Federal Government. A gleaning of messages, speeches, reports, and hearings suggests policies to which Forest Service Research should conform. Constraints on Federal employment, as a national policy, do not seem to limit decisions about levels of funding for Forest Service Research.
- Relation to historical trends reflecting recognition that the course of forestry research should not change drastically and should relate to changes both in demand for technology and in related fields of research. Status of and historical trends in funding for research are presented and analyzed. Factors affecting the current shape of Forest Service Research are indicated, and suggestions are made for achieving a desirable balance in Forest Service Research programs.

All indications are that substantially more public funds should be committed to research on renewable natural resources and that returns on investments will be justifiably high.

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